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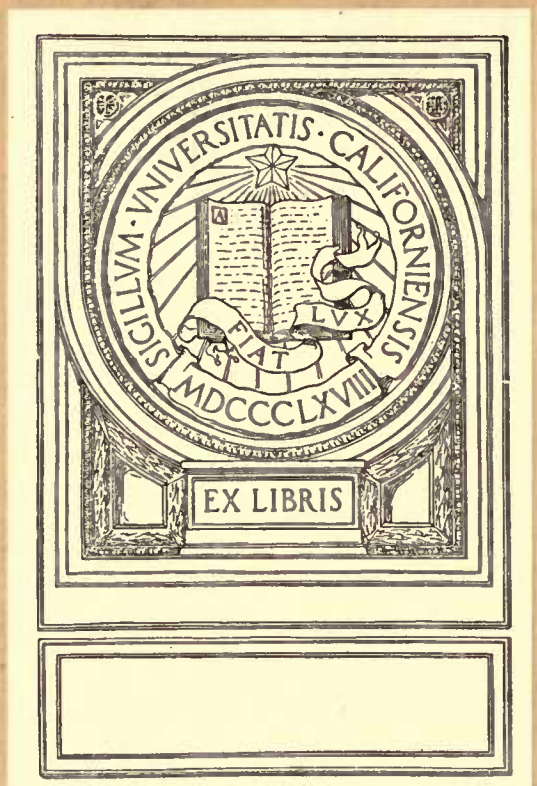
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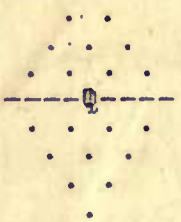
THE MANUFACTURE OF SUGAR

WITH

VARIOUS NOTES ON THE INDUSTRY

BY

DR. H. CLAASSEN.



----- SECOND EDITION -----

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Translation by Edgar Baruch.

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THE

MANUFACTURE OF SUGAR

WITH

VARIOUS NOTES ON THE INDUSTRY

UNIV. OF
CALIFORNIA

BY

DR. H. CLAASSEN.

SECOND EDITION

1904

Translation by Edgar Barnow.

PREFACE TO THE FIRST EDITION

The present volume should serve the technical sugar man as a stimulous towards noting and observing all the details which are so important in the manufacture of sugar; it should serve further as a guide to the beginner in the practical difficulties of the work.

The text and hand-books of sugar-making are in no way covered within the scope of this volume; in fact, it is taken for granted that the reader already has a very general knowledge of sugar chemistry and technology. In text books, one rarely finds the details of the technical work carefully outlined, and even the theorectical principles are not sufficiently emphasized; while the numerous difficulties rules, and devices of the work which are so essential to success, are invariably omitted. The practical sugar man is apt to find little new in the book, but may nevertheless be pleased to find short synopses of many of the problems which are apt to occupy his thoughts in the long pauses between campaigns.

A concise and accurate work on the industry can only be written by one who is in the practical side of the business; but any partiality of opinions expressed herein, must be excused for they have been based on actual experience. I believe though, that I have been as objective as possible in deriving my views, and I have gathered and carefully estimated the experiences of a great number of operators with whom I have come in contact, and have also carefully investigated the literature on the subjects. The principal original investigations which I have used, will be found in the bibliography inserted in the end of the book, from which the reader will be able to derive sufficient data to answer any special problems in which he may be involved.

Dormagen, April 1901.

DR. H. CLAASSEN.

PREFACE TO SECOND EDITION

By additions and changes, I think that the book has been bettered without in any way injuring the brevity or scope of the work.

Dormagen, November 1903.

DR. H. CLAASSEN.

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Lamar, Colorado, July 1905.

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APPENDIX I. Formulae, Tables, and Data.

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P R E F A C E

For the operation of a well constructed Beet Sugar Factory, a beet rich in sugar is the first and most important consideration. With this end in view the manufacturer of sugar must strive to urge the beet contractor to cultivate in such a way, that he can obtain a sufficiently large tonnage, a large amount of sugar and a pure juice. The surest way in which one can obtain this object is for one to pay for the beets not only by weight, but also on their sugar content; unfortunately this method is not practiced as generally as should be. One must be willing to give to the contractors a seed that is well adapted for the ground. At the same time the farmer should be thoroughly instructed in the proper methods of fertilization and preparation of the soil.

A beet rich in sugar which yields a pure juice is under all conditions worth more than a beet which gives impure juice, or than one poor in sugar. Under the latter conditions, the loss of sugar in working is higher, and the cost of working just as great, if not greater, because of subsequent difficulties in running. The sugar content, the purity of the beet and juice, do not depend entirely on the conditions which man controls. One has to contend with climatic and soil conditions. Where the climate allows, one should allow the beet harvest to remain in the field as long as possible; at least until the advent of the frosts, for the longer the period of vegetation lasts, the more sugar will gather in the beet, the purer will be the juice and the higher the tonnage. All these questions, important as they are, are minor considerations for the manufacturer, when the delivery of his beets begins.

BUDGET

CHAPTER I.

SUPERVISION, HARVESTING, STORAGE AND SILOING OF THE BEETS.

The time for starting the campaign does not depend entirely on the ripeness of the beets, but also on the quantity and the ease with which they can be worked in the factory. If a factory has a large crop to work, so that the campaign lasts long, it should begin with the work as soon as possible. The beginning or middle of September is best; as soon as the sugar contents of the beets will warrant their being worked. To decide this point it is essential to make tests of the beets in the field from the end of August until the time of ripening.

If a factory has, however, only a small crop, the campaign should be delayed as long as possible, so that ripe beets are worked from the start. In short, the work must be so arranged so that one can obtain the largest possible amount of sugar from the beets. If too early a start is made, one encounters the difficulty of unripe beets, poor in sugar; by starting too late so that the beets are stored too long, much of the sugar is lost by deterioration into starch.

In southern countries where beet culture has been established, other conditions govern the harvesting. The beets ripen there very rapidly in summer and must then be worked as soon as possible, before the rainy periods of autumn start a new growth, and the sugar contents of the beets deteriorates into starch. Besides this, in countries with early and periodic frosts one must arrange the harvest so as to have all of the beets out of the ground before everything freezes.

A regulated delivery is often arranged; in fact many factories state definitely in their contracts how many beets are to be delivered each week, even each day. But not all factories are in position to follow such a plan, for the sugar manufacturer is often

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confronted with great problems and troubles in the factories; in consequence, many plants can only lay down general rules for this supervision; while others follow none at all, but are compelled to take the beets whenever they are delivered.

These different conditions must be considered in harvesting and storing the beets. With a well regulated supervision, no large storage for the beets is essential, it is only necessary to have storage for one day. Where deliveries cannot be controlled, the beet bins must be larger. Beet bins that are too large are a source of injury, particularly so, when provided with beet troughs that carry hot or warm water. Under such conditions, the beets lie, not only days but weeks, in a warm vapor and deteriorate so that they are not only difficult to work but give a dark juice and a low yield of sugar.

Storage piles for beets are laid on the ground, or under it, in so called beet cellars, which are either thatched or left open. Beet cellars are undoubtedly the most economical form for the unloading of the beets, and the delivery of the same into the bins. It is of little importance whether or not the bins are covered, provided the beets do not lie too long. For storage of beets delivered by rail, the side walls of the bin should not be higher than the floor of the car, so that the beets can be shoveled out of the doors readily. The wider the bins are, the steeper the sides should be, so as to insure the beets falling into the troughs readily. The position of the bins should be such that the cars can be easily and quickly handled.

A very important problem in the delivering of the beets is the determination of the amount of adhering dirt. Sometimes this determination is merely estimated; most often though, a precise determination is made for a reliable result. The beets are dumped out in such a manner that 25 to 50 kilograms are caught on a beet fork. A

sample is taken from each wagon, the heads are chopped off and the beets brushed and washed. Since it is impossible to obtain closer than a quarter percent tare in each test; with car beets it is best to take several samples. The strictest control and supervision in the tare-room must be maintained, in order to keep peace between contractors and factories.

In the determination of dirt by washing, a deduction of 1/2% must be made for the water adhering to the beets. The heads should be cut off directly under the leaves; when the beets have tops that are large, green or full of holes, it is essential to take a deeper cut. The green portion of the beets and that full of holes is poor in sugar and gives an impure juice. Frozen, injured or rotten parts of the beets, so far as they are due to the farmer, are cut out. Injury to the beets during transportation to the factory is borne, as a rule, by the factory. One of the most annoying difficulties in transportation, is a sudden and heavy frost, that not only freezes the beets but makes the unloading almost impossible. Frozen beets must be worked immediately because they spoil very rapidly on thawing. Long exposure to cold, even to -1° C., is readily endured by the beets without freezing.

By exposure to a slightly greater cold, they freeze together without an actual freezing of the roots. The freezing first shows itself by the destruction of the cells. Beets which remain in the earth protected by their own covering, can stand heavy frosts, and even long periods of cold, with little or no damage; but on uprooting they must be worked immediately. Practice has shown, that beets rich in sugar, which generally have a firm structure, are less easily injured by cold than beets that are poor in sugar with soft flabby flesh. Where beets have to be transported in ships, care must be taken to have them uncovered, and the beets should remain in the holds as short a while as possible, for they easily heat and then work poorly and give a dark bad juice.

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The siloing of the beets at the factory. Those beets which cannot be utilized immediately on delivery must be siloed or stored in houses. In choosing a method of storage, one must take into consideration the loss of sugar and the cost of covering etc. A definite loss of sugar occurs by long siloing, for the beets breathe as long as they are sound, and the sugar stored in them is the material which is utilized in their breathing. The essential point in storing beets in the silo, is that they be stored as late in the season as possible; under no conditions before the middle of October and then freshly harvested and uninjured by cold. It appears to be best to store the beets in small covered mounds; even beets to be used for seed culture are stored in this manner. This method is impractical though for the factory, because it takes too much room and is too costly. The methods in use are those of large earth silos or piles. In mild climates large uncovered piles are preferable, because by such means the loss of sugar is small and but little space and labor are essential.

Beets suffer but small changes from small amounts of cold and later thawing, when they lie unmolested. Even after heavy frosts and sudden thaws only the top layers are injured. for the cold enters into the pile but slowly. In mild climates the loss of beets by thawing and subsequent rotting is very small. The beets should be properly distributed on the piles with a smooth even surface on top, in order to expose as small an area as possible to the weather. Attempts are often made to shield the beets under roofs. Those protected in this manner show a higher sugar content than those left uncovered, because they lose more in weight, but the actual loss in sugar does not amount to much. In localities where the beets gain in weight, roof coverings are to be recommended. Where the beets suffer no deterioration, the covering is hardly warranted because of the cost. In places with heavy

and early frosts the piles must be covered, but the best method is to use large earth silos or beet cellars provided with ventilation. The cellars serve their purpose best when the period of siloing is not too long and the beets are dry and have dirt adhering to them. In southern countries where the temperature is high during the period of working, the beets alter very rapidly and become bad very quickly.

In all methods of storage there is a greater or less alteration in weight, usually a decrease. Only such beets as are subject to rains and moisture of the earth or those which are kept on the bottom of the pile absorb much weight, that is when they are harvested in dry weather. The loss in weight is to some extent proportionate to the dampness at the time of harvesting and siloing. The more the air is witheld from the beets the warmer the center of the storage piles will be. In covered and ventilated piles or cellars, the loss in weight is at the greatest 5 to 10%.

The loss in sugar of siloed beets is proportionate to the temperature and the differences of moisture in the piles and in the atmosphere, and also to the extent of ventilation. The actual loss in sugar per day is about .010-.012% in large uncovered piles, .012 - .017% in ventilated piles, and .019% in large earth silos. These conditions prevail in mild climates where the average temperature during siloing is about 5°C., and the period of siloing lasts from the end of October until the middle of December. These figures are for sound uninjured beets. Injured beets or those from which the tails have been broken, those which have been too heavily topped, and those which have been mutilated with the fork or hoe in unloading, lose far more sugar. They suffer a large shrinkage and are subject to maladies such as Phoma, Rhizoctonia and Sclerotinia. When beets continue to grow during periods of siloing, it indicates that they are stored too warm

and too damp. With the formation of shoots there is a stronger breathing with big changes in composition and great loss of sugar. In the shoots themselves, there is little sugar, since their weight is made up of a definite percentage of starch from the beets, and they contain only from 3 to 4% of cane and invert sugars.

The temperature in the interior of the pile is about that of the exterior atmosphere. All temperature changes in the atmosphere are readily noticeable in the piles and silos, in the uncovered piles more so, naturally, than in those covered with earth and protected from the atmosphere. Since by breathing of the beets heat is developed, the temperature in the piles becomes slightly higher than the average temperature of the atmosphere. The greatest differences occur when the air is kept in motion. By the perservation of the beets, an increase in the organic nonsugars in the juice is prevented. while the sugar and the insoluble non-sugars remain in such condition that they can be separated in the work.

CHAPTER II.

TRANSPORTATION AND WASHING OF THE BEETS.

TRANSPORTATION FROM THE BINS TO THE FACTORY.

Formerly beets were carried from the storage piles to the wash-houses by small cars or by means of baskets. The practice in vogue today is that of floating the beets into the houses by means of troughs. The troughs are arranged in the center of the bins so that the beets fall down the sides and into the water with little attendant labor. The bottoms of the bins are made either solidly or of lattice construction. In the latter case, dry earth and debris falls through the interstecies, and the troughs do not have to carry so much dirt to the washing machines. Another advantage is, that one is able to remove the dirt from under the bins. However, under conditions where damp weather prevails during the period of harvest, the mud surrounding the beets renders the lattice bins almost wholly useless.

The troughs are constructed, as a rule, out of bricks with cement lining on the inside. Where movable troughs are desirable, iron is used. They are, as a rule, about 500 - 600 m.m. high, and from 300 - 500 m.m. broad. On the upper edge there is a "set back" for the cover boards, which are of wood, sheet, or cast iron. In most cases the troughs are set on a grade of .8 - 1.0%, on straight stretches, and 1. - 1.2% in the curves. When the beets are dirty and covered with weeds, leaves etc., the grade has to be greater. For the proper operation of the troughs, the beets must not be dumped in at more than one place at the same time, and the point of delivery must be free and open. If the water does not run away freely, the lifting device must have sufficient capacity to take the water away fast enough so that it does not back up in the trough. The slightest obstruction in the trough blocks not only the beets, but stones and sand as well, and causes very aggravating

CHAPTER II.

TRANSPORTATION AND WASHING OF THE BEETS.

TRANSPORTATION FROM THE PILING TO THE FACTORY.

delays. The amount of water to be used depends on the amount of beets to be carried into the house, the size and grade of the trough. If there is an insufficiency of water, the size and grade of the trough is of greatest importance. The water utilized for floating in the beets is usually taken from the condensors. When this water is cooled and used again in the factory, it is necessary to use the water from the washing machines after settling the dirt out of it.

It is apparent that quite a loss in sugar occurs by the beets remaining some time in warm water in the troughs, but these losses are, as a rule, small. The average results show that with 100 Parts beets, in a trough, 220 m. long, with healthy beets and warm water (40 - 45°C.) the loss is .02-.03%, though sometimes as high as .05%. With frozen or injured beets or warmer water, the loss is .1 - .57%.

Under usual conditions, the loss of sugar in the troughs is small enough to be negligible, particularly so when the troughs are short and the water cold. The losses depend on the length of the troughs, the time of immersion, and the temperature of the water. With frozen beets as well as those lumped together by dirt, cold water cannot be used; the frozen dirt and debris has to be thawed out, and under such conditions the loss of sugar cannot be considered. During the immersion of the beets, they absorb some water and increase in weight, wilted and dry beets more so, of course, than those that are fresh. The absorption rarely exceeds more than 1/2 to 1%.

A little distance before the point of delivery, stone catchers of various construction are used. An undercurrent of water which separates the dirt and stones from the beets is often installed. Prong arrangements are used to catch leaves and straw, particularly the material that floats on top.

The transportation of the siloed beets is usually managed by use of wheel-barrows, though movable troughs are used whenever possible. These are arranged so that they can be pushed to any desired spot and the beets are thrown in by hand.

The best means of taking the hot condensor water to the beet troughs is in open channels. Pipes are not only too costly but are often obstructed by a deposition of scale from the hot water.

The washing of the beets. The troughs discharge directly into the washing machines or are provided with lifting devices in the form of wheels, screws, or bucket elevators, which lift the beets either alone or with water. Before the beets enter the washing machine, they must be freed from the water of the troughs, so that the dirty water does not contaminate the fresh water of the machine. Many factories use unclean water for washing, such as the drain water from the diffusion battery and pulp presses, or clarified drain water from the house. Fresh warm water should be used whenever possible so as to avoid taking annoying skums into the battery, which spoil the juice. Under all conditions the beet should finally be washed under clean water.

The washing machines used are long machines with radial arms, with large spaces for catching stones. Drum machines, because of their difficulty in working are no longer used. Vertical cylindrical machines have been used because of their ability to get rid of the stones, straw and leaves; but since the beets are now freed of most of their debris in the troughs, these machines are not much in vogue. The washing machines serve their best purpose in protecting the knives and so furnishing better cossettes.

CHAPTER III.

THE WEIGHING AND CUTTING OF THE BEETS.

From the washing machine the beets are lifted by means of an elevator into a storage bin. In early days it was considered essential to dry the beets as well as possible after taking them from the washer, because they passed directly to the pay scales. This method is no longer in use, but it is still important to drain them as much as possible, in order to get off the dirt and sand that remains suspended in the water and injures the cutters.

Many different kinds of weighing machines are in use. Most factories do not weigh the beets after washing them, but take the rough weight from the wagon scales after deducting the tare, for the amount of beets worked; or else calculate the amount from the diffusion juice. Both of these methods are entirely unreliable, and the only correct way to know the amount of beets worked is to weigh the beets after washing them.

Since reliable weighmasters are difficult to obtain, it is best to utilize automatic scales which insure accurate control, and in the end are cheaper than manual weighing.

From the scales the beets fall into the cutter or into a bin from which they are elevated into the slicer. Where space and height permit, the first method is preferable, for the cutter can be filled more readily and evenly and can be kept constantly full, a condition that is absolutely essential.

The cutting of the Beets. The beets are nowadays cut or sliced into cossettes by means of a revolving horizontal disc fitted with a number of knives. Centrifugal cutters are but sparsely used. Of late a drum machine is coming into use, the knives of which, are set on the periphery of a drum that revolves on a horizontal axis. The beets fall through a slotted opening in the drum and are pressed by a

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Many different kinds of weighing machines are in use. Most factories do not weigh the beets after washing them, but take the tonnage from the wagon scales as the beets are dumped into the bin. For the amount of beets received, or else calculate this amount from the difference in weight of wagons loaded and unloaded, and the only accurate way to keep the account of beets received is to weigh the beets after washing them.

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The cutting of the Beets. The beets are normally cut or sliced into cossettes by means of a vertical or horizontal disc fitted with a number of knives. Certain cutters are specially used for cutting a drum resting in cradle-like bearings of which are on the periphery of a drum that revolves on a horizontal axis. The beets fall through a slotted opening in the drum and are pressed

crescent like baffle plate, onto the knives. The machine should work easily and give a long cossette. The ordinary machines differ from each other only in size and arrangement of the space above the cutter disc.

The diameter of the discs is not greater than 1200 - 1500m.m., though in other countries they are sometimes extended to 2500 m.m. Small wheels are run at a speed of 100 - 150 R.P.M., while the large cutters are run as low as 50 R.P.M. In general, the large cutters revolving at a slow rate of speed, give the best cossettes; but more time is consumed, in the larger machines, changing knives and removing rocks.

The cutters are usually driven by means of belts, though there are some machines driven by individual steam drives, or electric motors, in order to control the speed. Such arrangements are useful but expensive.

Over the cutter disc is a cover which must not be placed too close to the walls, or the beets will bridge over the knives. The slicer should be designed so that the greatest possible amount of beets should fall on the knife boxes. The cutter consists of two concentric cylinders with only enough room between them for the knife boxes. This space should be a trifle wider than the length of the boxes. It is best to make the inner cylinder, or cone, a low convex cap, so that the beets will slide off readily onto the knives. The outside cylinder should be from 1.5 to 2 m. high, so as to give as large a storage as possible above the knives. Over the cutting space, attached to either the outer or inner cylinder, there should be a number of baffle plates to prevent the beets from sliding around with the knives. When the fall of the beets is unhindered, the cutters can be run more rapidly.

crescent like baffle plate, onto the knives. The machine should work easily and give a long cassette. The ordinary machines differ from each other only in size and arrangement of the space above the cutter disc.

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The outer cylinder should be provided with doors for the removal of foreign matter such as stones, iron, wood or coke; and should also have a number of holes through which one can stick iron rods to keep the beets from falling on the boxes when the cutter has to be cleaned. The moment any foreign matter gets into the machine, operations should be suspended immediately; for this purpose a reliable brake should be provided.

The number of knife boxes used in the cutters vary considerably. Naturally, in the cutters of larger diameters, a greater number of larger boxes can be used than in small machines. The boxes can be placed as closely together as they can go, providing the discs are properly braced underneath. The German knife boxes are about 280mm., long and 90 to 180 mm., broad. The boxes are somewhat larger in the big cutters but vary greatly in size and construction. The important features for a good box are :--------

1. A good hard material that will not wear out or break easily.
2. Solid construction, without parts subject to heavy wear or difficult to handle.
3. The passage for the cossettes should be as free as possible.
4. Ready means for lifting and placing the boxes, and also easy and rapid means for obtaining the correct height and distance of the knives, from the frame.
5. Light stiff frames that fit correctly into the position for the boxes.
6. The boxes must all fit evenly into the discs without the projection of corners or edges.

When these conditions are all fulfilled, the construction of the boxes makes little difference. Those of simpler construction are the most practical. With fibrous beets or those carrying small stones, the frames are serrated so that only enough of the small points of the knives project to take hold of the beets; the stones readily fall through the large openings in front of the knives. The knives must fit very accurately in the frames, for the slightest irregularity from

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1. A good hard material that will not easily get worn out or break easily.
2. Solid construction, without parts subject to bulky wear or difficult to handle.
3. The passage for the segments should be as free as possible.
4. Ready means for lifting and placing the boxes, and also easy and rapid means for obtaining the correct height and distance of the knives from the front.
5. Light split frames that fit correctly into the position for the boxes.
6. The boxes must all fit evenly into the discs without the projection of corners or edges.

When these conditions are all fulfilled, the construction of the boxes makes little difference. Those of simpler construction are the most practical. With fibrous beets or those containing small stones, the frames are arranged so that only enough of the small points of the knives project to take hold of the beets, the stones readily fall through the large openings in front of the knives. The knives must fit very accurately in the frames, for the slightest irregularity from

the proper position gives poor cossettes. Hence, it is not advisable to put old boxes in new discs nor to use new boxes in old discs.

The knives which are used for the small boxes are about 140mm., long, and two can be placed in one box. Their width is regulated by the size of the box and they range from 7 - 9 mm., in thickness. There are three kinds of knives in use.

The "Dachrippen" knives have the advantage of ease of handling, and a full cut. They are made in various sizes from 20 - 40 divisions to the knife, so that the divisions are from 3 1/2 to 7 mm. apart. The sharpening of these takes much time and care, and is accomplished by means of steel frases.

The "Konigsfelder" knives take only a half cut, and the divisions are only 5 - 7 mm., broad. They are sharpened more easily and quickly and do not fill up with fibres so readily. They are sharpened by either frasing or filing.

By correct adjustment of either of these knives, and with proper distribution of the beets, a long clean cossette can be obtained. The ridges of the knives should, in all cases be made part of concentric circles, coincident with the diameters at which they are set.

Since it is advantageous to have a symetrical cut on all of the cossettes, in order to get a proper digestion, the double knife is frequently used; this gives a three cornered cossette. The double knives are encased in a box with an ordinary knife superimposed on a flat cutting edge. The first knife cuts out a three cornered edge while the second cuts it smooth again. While the cossettes cut by this method are entirely symetrical, they are not as well adapted for the digestion in the battery, as shredded cossettes. It is impossible to

recommend any single method of cutting. Good results can be obtained with most any knives, provided they are sharp, will tempered and properly set in the frames. The knives are sharpened on machines, with emery, corundrum, or carborundrum wheels, and the finishing touches are put on with a fine file.

To obtain good cossettes, the beets must be well washed and free from stones. When the beets are unhealthy and unsound, it is best to increase the size of the cossettes. Good cossettes are essential for good diffusion work, and any improvements that can be made in the wash-house to accomplish this end, no matter how costly, will be well warranted. The cossettes depend, to some extent. on the structure and condition of the beets. It is very difficult to obtain good cossettes from hard fibrous beets, or those which have gone to seed.

From the cutter the cossettes fall into wagons, elevators, or conveyors, which take them to the diffusion battery.

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CHAPTER IV.

D I F F U S I O N.

The extraction of the sugar out of the cossetts takes place in a number of extraction bodies combined to form what is called a Diffusion Battery. The number of cells in such a battery varies from 6 to 16, the smaller number being used in the short, or divided batteries, which are heated to a high temperature and through which the juice passes slowly, while the greater number is used in connection with lower temperatures and with a high velocity of the juice. In general batteries of from 12 - 14 cells are now preferred, - the cells being erected in straight lines. The method of erecting the cells in a circle having the Slicer in its center is no longer used.

The form and volume of the cells varies greatly, the capacity of the cells varies all the way from 1.2 - 6.0 tons, but at present large cells of from 3.0 to 5.0 tons capacity are preferred. The small cells which used to be used in Austria (there were some in use which had only a capacity of 180 lbs.), are to be considered as altogether impracticable. But also in the case of large cells, bad conditions may arise, especially when run at low capacity, and when the cossetts are not very good or are cut too fine.

The shape of the cell should be such that the extraction shall be as good and as regular as possible at all points without retarding the flow of the juice. But these conditions cannot be combined in such a way as to completely fulfill them all. At first in considering the shape of the cells we have to consider the ratio between height and diameter. The extraction is naturally the better, the greater the height of the cells and the smaller their diameter. But with the height, the length of the space filled with cossetts, through which the juice has to flow, also increases, and with this also the resistance which the stream

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has to overcome. With the smaller diameter the size of the lower sieve surface on which the cossetts rest also decreases, and as, besides this, some of the holes become stopped up by cossetts, the flow of the juice is very materially slowed down.

It has been tried to determine by experiment which relation between diameter and height is best, but rules which would apply in all cases cannot be made, as the resistance offered to the flow of the juices is not only determined by the length of its path through one cell, but also by the number of cells in use, and besides this, by the area of the lower sieve which allows free passage of the juice, the thickness and other characteristics of the cossetts and the action of the cossetts during diffusion, especially during warming. As these last two items are not alike in any two factories, and also vary greatly in one and the same factory, it is clear that every change in the mode of working would require different relations. Nevertheless it is possible to put up some rules by means of which the chief dimensions of the cells should be determined. If very thin cossetts are to be used it will be found best to use low vessels with large diameters. But in case thick cossetts are to be used, the vessel should be made of a greater height and of a smaller diameter. For average working conditions and an average size of cells a ratio of diameter to height of 1:1-1/4 to 1:1-1/2 is now mostly used for ordinary cylindrical vessels. A ratio of 1:2 is found less often, as it is preferable to increase the number of cells in the battery, making the ratio of the cells 1:1-1/2.

The above refers to ordinary cylindrical vessels. Experiments, which will be mentioned again later, have shown that the extraction at different points of the cell may vary greatly. Thus the opinion developed that this defect might be remedied by changing the form of the vessel, and conical vessels were actually put in use. Still it does

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not seem probable that the shape of the vessel, unless it is too ab normal, will have any decided influence upon the extraction.

The form of the lower part of the cell is determined by the mode of emptying. In case the emptying takes place through man holes in the sides of the vessel, the lower part is usually cylindrical, the lower one being flat in this case and having the diameter of the cell. Some cells have the bottom opposite the manhole rounded off so as to make the emptying of the pulp easier. In cells emptying from the bottom the form of the vessel is also cylindrical at the bottom, in case the lower cover has the same diameter of the vessel, which is nearly always the case when the diameter is not too large; or it is conical, the cover fitting on the small end. In cells emptying at the bottom, the sieves are placed in the cover, and in those having a conical lower part they also form the conical surface. In the latter case it was found to be very serviceable to make these holes small and further apart in the upper part of the conical sieve than in the lower.

When the cells, whatever may be their form, are connected up to make a battery, their chief requirement for this battery is to make as little resistance to the flow of the juice as possible. In order to improve the flow the following methods may be used:

1. Increase the water pressure on the last cell.
2. Reduce the counter pressure in the measuring tank.
3. Increase the size of the pipe line and valves.
4. Perfect evacuation of air.
5. Increase free passage through lower sieves.

Of all the methods it is in most cases found to be of most use to increase the free passage through the lower sieves. It will not suffice to have this free passage a number of times larger than the area of the pipe, as the pulp will cover and stop up a greater part of the holes, especially when the cossetts are very thin and soft.

The free sieve surface should therefore, be as large as possible, and those sieves are the best which have the greater number of holes or slits of correct size, and at the same time are strong enough to resist the pressure exerted on them. Sieves which were formerly placed in the upper neck of the cells are now no longer used, as they are not only absolutely useless but also harmful, as due to their limited size they impair the flow of the juice very much, as soon as pieces of pulp from the before placed cell flow over it and stop up the holes.

What effect the increasing of the water pressure in the last cell will have, becomes very doubtful as soon as the difference in level between the water tank and the measuring tank exceeds 32.8 feet. According to the well known law, the velocity of flow increases as the square root of the pressure. But due to the higher pressure the cossetts are also pressed the harder against the sieve. With strong hard cossetts this may be no drawback, but in case the cossetts are small and soft an increase in water pressure may even have a harmful effect. The remedy does not aid when it is needed the most. It is, therefore, not correct to have a pump acting directly upon the battery, because in this case, the harmful action of the pound of the pump is added to that of the increased pressure. Centrifugal pumps are better suited for this purpose.

The reduction of the counter pressure due to the measuring tank by introducing a suction pump between it and the battery is also of service only in certain cases. But this also may act injuriously in case the suction becomes too strong so that air is drawn into the cells. For this reason and also due to the greater complications and cost, the suggestion of introducing centrifugal pumps between all the different cells, was never made use of. In order to reduce the pres-

sure of the cossetts on the sieves, chains or grates were hung inside the cells. A certain amount of success was met with by doing this, but as all these arrangements make the emptying of the cell much more difficult, they are taken only as a last resort in case frozen or spoiled beets are used. The bad effect of large amounts of air upon the flow of the juice is explained by the fact that the juice travels from the top toward the bottom, while the imprisoned air has a tendency to travel from the bottom toward the top. It is due to this fact that large amounts of air or gas, especially when distributed through the whole cell, are a great resistance to the flow of the juice. For removing the air which collects at the upper part of the cell we use air cocks, or what is better, automatic air vents. Under normal conditions, or we when only water is used for pressing, the automatic air vents are not necessary. But in case the juice is pressed out of the last cell by compressed air, it may happen that, due to leaky valves the air from the pressure line may get into the other cells and then the automatic air vents may be of great service, and also in case gases are generated by the cossetts during diffusion.

Now, whether one is in general satisfied with the manner in which the juice is flowing or not, in all cases it is advisable to provide calorisators with pressure gauges. If this is done one knows instantly at which point the pressure is decreased the greatest and where the flow of the juice finds the greatest resistance.

Pipe lines and valves of large cross sectional area are certainly of some value but the benefit of their action is often over estimated. In case the velocity of the juice in the pipe does not exceed 3.28 to 4.92 ft. per second, an increase in the size of the pipe can be of no advantage; the poor pressure is then due to another cause.

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To warm the juice in going from one cell to another, closed coil heating tubes are used or the steam is directly injected into the juice. In general the closed coil heaters are preferred, as they can be cheaply heated by means of vapors from the evaporators. In case the steam is injected into the juice only expensive boiler steam can be made use of. The claim that the juice heated by this latter method is thinner due to the steam injected into it than that heated by closed pipes , was not supported by experiments. Without doubt all the steam injected is condensed in the juice and the juice will, therefore, be diluted in the calorisators, but the last concentration takes place in the freshly filled cell, after which the juice is no more heated in the battery, and consequently a dilution of the drawn off juice is hardly noticeable. Then also, the fact should not be overlooked that the closed coil heater has a bad effect upon the density of the juice, for the juices in the cell become more concentrated the more cossetts the cell contains. Less space is filled with juice, and all such spaces are lost for the Diffusion process. The closed tube heaters also have the drawback that due to leaks, losses in juice may occur, which is not possible when steam is injected.

In order to save steam in the diffusion process, warm water is often used as pressure water. For this the water from the condensers, the condensed water from the evaporators, or water which has been heated without cost by the last vapors from the evaporators, may be used. The water is heated usually to only about 104°F, but can be used hotter in case the cells are emptied through the bottom or by means of compressed air. In case the pulp is not dried but fed when fresh, or is siloed, it must be entirely cooled before it is pressed, for when they are pressed while still hot they get spoiled in a short time. In this case it is usual to work with two water lines in such a way as to start

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with hot water, and press off and rinse out after emptying with cold water.

The work with the diffusion battery is nowadays conducted differently in every factory. Alike in all processes is the continuous working, the heating of the juice between the cells, and the direction of flow of the juice. In all cells the juices flow from the top towards the bottom except in those freshly filled with cossetts, when the juice is passes from the bottom towards the top for a short time in order to drive out the air. All the rest of the conditions,- above all, the temperatures, the time of drawing and the density of the drawn juice varies between wide limits. As the size and number of cells in the battery and the constituency of the betts and cossetts very greatly, a method which will do for all cases cannot be imagined. Therefore absoluted rules cannot be given, but only general ones by the aid of which the best method of working for any one factory must be determined.

The first requirement for a successful diffusion is naturally a clear soft water, containing as small an amount as possible of dissolved salts. In case such water cannot be had, the purity of the diffusion juice suffers- this being especially the case where factories have to contend with small amounts of water and are forced to use purified waste water, in which a large quantity of mineral and also organic matter remains in solution, for diffusion.

A good diffusion should give well extracted pulp and juices which are as pure and concentrated as possible. The work with the diffusion battery is not as the name implies, and as was first thought when this method of extraction was first introduced, a diffusion pure and simple, but is at the same time, a laxivation and digestion. Even in smooth cossetts many cells are torn, and the more so the thinner the cossetts are. With ordinary cossetts which are more or less rough,

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the number of torn cells is much greater and from these the contents are simply washed out. Then also the cell walls, which when perfect cause diffusion, as well as the contents of the cell, contain substances which dissolve when kept in contact with water for some time. These are especially Pectins and organic salts of Calcium and Potassium.

During the treatment of the cossetts in the diffusion battery three actions take place at the same time, namely:

1. The washing of the juice out of the torn cells.
2. The dialysis of the soluble substances out of the perfect cells.
3. The dissolving of the substances which are indissoluble in the beet.

While the first two, especially the dialysis, are those actions which we strive to obtain in diffusion, the third is a harmful effect which should be reduced as much as possible. It is a sad coincidence that those conditions which are the best for a good diffusion are also the most favorable to cause the dissolving of the indissoluble substances.

The dialysis takes place the more rapidly the higher the temperature used, the thinner the juices and the thinner the cossetts; it is more perfect the longer it is allowed to act. But hot, slow working and thin juices as well as thin cossetts are also the best conditions for dissolving the indissoluble substances of the cells.

It is the work of the technical sugar man to at all times consider which methods under the given conditions would give the best result in diffusion, but first of all, which will allow the best extraction of sugar . At the same time it should be noted that one method of procedure may take the place of another. For instance, the time of

duration of the diffusion when higher temperatures and a stronger flow of juice are used, may be shortened, while lower temperatures may be used in case the time of duration of diffusion is increased and the cossetts are made finer.

If the diffusion could be conducted by using thread like cossett this would be an ideal mode of working, as the entire diffusion would take only a few minutes. Only small vessels would then be needed and only a small part of the undissolved substances of the cells and cell walls would be dissolved, while the juice would, nevertheless, be highly concentrated.

Unfortunately, it is not possible to produce such cossetts, and neither would it be possible to keep up a large enough flow of juice when using such fine cossetts. Most factories cannot even continually produce cossetts of 1/12 inch in thidkness, or smooth cossetts of a somewhat constant cross section. The time of duration of diffusion must be determined by the degree of extraction of the largest cossetts. The greater their number the longer diffusion must act in order to obtain a good average extraction. By the time a good average extraction has been reached, the extraction of the sugar from the thinner cossetts is nearly perfect, and quite an amount of non sugar has already been dissolved from their cell walls, while the thick cossetts still contain far more than the average amount of sugar that should be kept in them. Therefore, in order to obtain a good diffusion the cossetts should be made as uniform and thin as possible, without having them thereby impair the flow of the juice.

There is an upper limit for the temperatures on the battery which lies where the cossetts begin to get soft, or when they become scalded. Scalded cossetts will pack so tightly upon the lower sieve that the flow of the juice becomes very slow. For different kinds of beets the temperatures vary at which the cossetts become scalded. In

general, freshly harvested ripe beets will stand a higher temperature than beets which have been siloed, but the method of fertilization and climate during growth also have an influence upon this. In the case of sound beets the juice may be heated to 176 to 183°F without having to fear any overheating. It should also be noted that the temperature of the cell contents is always a number of degrees lower than the thermometer in the calorisators registers. No cossetts will stand a temperature above 194°F without getting soft. Naturally a great deal depends upon the length of time during which the cossetts are subjected tothis higher temperature. This is why it is possible to use higher temperatures in connection with quicker work, i.e. a more rapid exchanging of cells than with slow diffusion.

When unsound, rotten or frozen beets have to be handled, high temperatures cannot be used under any conditions, as the cossetts from such beets, that is where the beets can really be sliced into the form of cossetts, are soft from the start and get softer even in case comparatively low temperatures are used.

The temperatures to be used are also different for long and short batteries and for large and small cells. The shorter the battery and the smaller the cells the higher the temperatures that must be used, the greater the number of cells that have to be kept at the high temperature, even the pressure water should be quite hot, while in the case of long batteries with large cells, the temperature has to fall in the direction of the first cell, and only a few cells should be kept at the highest temperature.

In order to draw off juices of high concentration, which, besides a good extraction, we should always strive to obtain, the cossetts should, during the entire process of diffusion, be surrounded by as little liquid as possible. The concentration will become the higher,

general, freshly harvested ripe beets will stand a higher temperature than beets which have been stored, but the method of fermentation and climate during growth also have an influence upon this. In the case of sound beets the juice may be heated to 176 to 185°F without having to fear any overheating. It should also be noted that the temperature of the cell contents is always a number of degrees lower than the thermometer in the calorisator registers. No cossette will stand a temperature above 194°F without getting soft. Naturally a great deal depends upon the length of time during which the cossettes are subjected to this higher temperature. This is why it is possible to use higher temperatures in connection with quicker work, i.e. a more rapid exchanging of cells than with slow diffusion.

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other things remaining the same, the more cossetts by weight are contained in a cell or the higher the so called filling is. In this direction the large cells again have an advantage over the small ones. By using stampers it is possible to get 120 to 130 lbs. and more of cossetts per 1 hl. into the large cells, while in case of smaller ones, especially when the working is rapid and there is no time for stamping only 110 lbs. per 1 hl. can be gotten in. Evidently, the condition in which the cossetts are has a great influence upon the magnitude of the filling, as thin cossetts and those from fresh beets can be packed tighter than thick cossetts and those from dry beets.

Basing our conclusions upon the above treatment, we can distinguish the following typical methods of working from one another. They have their advantages and disadvantages depending upon local conditions.

(1) In the work with a long battery of from 12 - 14 cells of small capacity - 1.2 to 1.8 tons, the cossett must be thin and the temperature of the whole battery up to the last cell must be kept as high as possible. Warm pressure water should be used. The diffusion should be short, i.e. last from 1 - 1-1/4 hours. Hence, the change of cells and the flow of the juice must be rapid. The drawn off juice will usually exceed the normal amount.

(2) In the work with a long battery of from 12 - 14 cells of large capacity - 3.0 to 5.0 tons, the cossetts should not be too thin and should be of uniform size. The temperature must be high in the front and must drop toward the back a little more than in case (1). The pressure water should be cold or only slightly heated, the diffusion should last from 1-1/2 to 1-3/4 hours, the change of cells should be less and the flow of juice slower than in case (1). The drawn off

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(2) In the work with a long battery of from 12 - 14 cells of large capacity - 5.0 to 8.0 tons, the cossette should not be too thin and should be of uniform size. The temperature must be high in the front and must drop toward the back a little more than in case (1). The pressure water should be cold or only slightly heated, the diffusion should last from 1-1/2 to 1-3/4 hours, the change of cells should be less and the flow of juice slower than in case (1). The drawn off

juice can be reduced to 100% of the filling.

(3) In the work with a short battery with from 6 - 8 large cells, the cossetts should be kept as in case (2) and the temperature of the entire battery should be maintained as high as possible. The pressure water should be warm and the diffusion last from 1/1/4 to 1-1/2 hours. The change of cells should be still smaller and the flow of the juice slower than in case (2). The amount of drawn off juice will be somewhat higher than in case (2).

When one must work with a diffusion battery already installed in a factory, one can select the most appropriate of the above given three methods of working, in order to secure, together with a maximum capacity, the highest concentration of juice and a good extraction.

How far the extraction should be continued is entirely a matter of calculation. In case the battery is comparatively small and the quantity of beets to be worked is large, it would not be correct to try to get a thorough extraction by decreasing the capacity or by drawing off more juice, as the gain in the sugar would be balanced or over balanced by the increased cost of operation, due to running at low capacity the loss of sugar in the stored beets and the coal consumption. But if the battery is plenty large, it would be wrong not to drive the extraction as far as possible by using the correct temperatures and time of draw of diffusion, out of fear that the juices obtained from the last cells would have too low a purity, and would therefore, have a bad effect upon the rest of the juices. Although this last opinion is wide spread it can only be applied in exceptional cases- as in working very poor, frozen and rotten beets. In case of sound and ripe beets the thin juices from the last cell, when separated, often have a low purity, but by separation and saturation so many non sugars are precipitated or so changed that the purity is very considerably increased.

In case the syrups made from the purified juices are correctly neutralized, the sugar can be profitable extracted by crystallization, as they are otherwise costless and are obtained without an increase in the working cost or coal bill. The fact that the carbonated alkalies, which are found in great quantities in the separated and saturated after juices of the diffusion, and have to be carefully neutralized before they are worked alone, when worked together with the diffusion juice, as takes place when high extraction is used, act favorably instead of unfavorably is explained by the circumstance that the thin juices usually contain soluble salts of calcium, which latter is precipitated as calcium carbonate upon the addition of the carbonated alkalies. In case such soluble salts of calcium are not present in the separated juice, a saturation of the thick juice with sulphurous acid will act very favorably.

In considering the question of the limits of extraction we should not leave the fact unmentioned that the extraction of the cossetts is different in different parts of the cell, and that the extraction of sugar, as well as of non sugars is naturally less in the thicker cossetts than in the thin ones. Experiments made, to determine the difference in extraction in different parts of the cell, gave varying numerical results, but all proved, as we should naturally suppose, that the percentage of sugar in the pulp increased from the top towards the bottom, so that the pulp near the bottom sieve contained 0.1 to 0.2% and sometimes more sugar than that near the top. If conical sieves are used as in cells emptying from below, the extraction towards the center of the conical part may possibly be very poor if most of the juice flows through the upper holes in the sieve. In large cells a higher percentage of sugar is sometimes found in the pulp in the upper corners when the cylindrical part is surmounted by a flat top. All these variations

In case the syrups made from the purified juices are correspondingly lighter colored, the sugars can be profitably extracted by crystallization, as they are otherwise cooleless and are obtained without an increase in the working cost or coal bill. The fact that the carbonated alkalies, which are found in great quantities in the separated and saturated after juices of the diffusion, and have to be carefully neutralized before they are worked alone, when worked together with the diffusion juice, as takes place when pick extraction is used, act favorably instead of unfavorably is explained by the circumstance that the thin juices usually contain soluble salts of calcium, which latter is precipitated as calcium carbonate upon the addition of the carbonated alkalies. In case such soluble salts of calcium are not present in the separated juice, a saturation of the thick juice with sulphurous acid will act very favorably.

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in extraction appear only on a small scale when the extraction is good in general, but become very large when the extraction is poor, or when the pulp contains as much as 0.5% sugar on the average. This fact also shows that the extraction should be carried quite far, as only then the actual loss in sugar tallies with the determined loss.

The amount of juice drawn off per 1 ton of beets is determined by the degree of extraction. Before increasing the draw of the diffusion juice, in order to improve an unsatisfactory extraction, one should try to do so by improving the cossetts, using higher temperatures by an increased heating of the last cell, or a better filling of the cells while keeping the flow constant.

The measuring of the diffusion juice is usually conducted in open pre-heaters. The amount drawn off is either indicated by an ordinary float or by a controlling apparatus with regulating attachment. This method of measurment must be considered quite crude, at any rate it is impossible to get exact figures by means of it. Sufficiently accurate figures may be obtained by measuring the juice in a tank provided with an overflow, if from this tank all the juice is drawn after each filling and its volume has been predetermined by filling it with a known weight of water. If the overflow is adjustable so that the capacity of the tank can be regulated by means of it, such a measuring tank will come up to all requirements, and will even take the place of automatic measuring apparatus, of which there are a number of commendable forms.

In many cases the juice of every draw is spindled. If stress is laid upon the getting of a good average sample, this mode of control is of great value. But when it is suggested to regulate the draw according to its density, so as to immediately increase the draw when the density rises and decrease it when the density falls, the suggestion

seems to have no sound basis. The beets should be well mixed when they get to the slicers and the cossetts become mixed still better, so that the filling of the cells does not vary much in its percentage of sugar each day, and the density of the juices varies but little when the filling is uniform. Then also, the density of the draw and the extraction depend upon so many things besides the flow of the juice, that such a regulation of the flow may even have bad consequences if the percentage of sugar in the cossetts in the different cells really is different. Consequently, the best rule is to change the rate of flow only when the percentage of sugar in the pulp is no longer normal, and can be decreased in no other way. Such a regulation is only seldom necessary and can be easily conducted with ordinary measuring tanks.

By experiment it was shown that concentrated diffusion juices usually are of higher purity than thinner ones, and this fact becomes the more noticeable when the pressure water is impure. For this reason and the coincident economy in coal, one should strive to draw as small an amount of juice as possible. Many factories get along with a draw of 9.1 HL per one ton of beets. More than 10 to 10.5 HL per one ton of beets should never be drawn where coal is expensive, but in case the extraction is not great enough it is better to make appropriate changes in the diffusion battery.

When one wants to insure oneself that the method of working used is correct, samples of juice should be tested simultaneously from all cells of the battery for purity and percentage of sugar. From the determined percentage of sugar one can find the increase for each cell. If the found figures are now platted, the numbers of the cells being taken on the axis of abscissa and the per cent increase in sugar on the axis of ordinates, we get a curve, which in case the method of working is correct, will have a definite regular shape . But if the method of

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diffusion is incorrect this curve becomes irregular in shape, which means that the extraction in the different cells is not uniform, as it ought to be, and the total work done by the battery is not a maximum.

The purity of the diffusion juice does not always allow us to draw conclusions as to the value of the juices, as not only the constituency of the non sugars varies, but also because it is unknown as to the amount of these non sugars that will be removed during separation and saturation. It is hence easily possible and often happens that a diffusion juice of low purity gives a better fillmass than one of higher purity. Nevertheless the determination of the apparent purity of the diffusion juice has a certain practical value, as it is often possible by its aid to draw a conclusion as to how the juice may act and what troubles may arise in later stages of the process. Such conclusions are only allowable then, when many and regular purity determinations are made, and only then is it possible to judge whether a change in the working of the diffusion, especially a more rapid and hotter working will be advantageous to the purity of the juice.

It must be considered quite wrong to judge the value of the diffusion by comparing the purity of the diffusion juice with the purity of the pressed beet juice, and by believing the diffusion the better the greater the difference in the purities. It is well known that the purity of the pressed juice of the same kind of beets varies with the fineness of the pulp and the applied pressure, and that beets grown under different conditions give press juice of very different quantity and composition. There is therefore, no press juice which is characteristic of the tested beets, and therefore, comparisons with it are untrustworthy.

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Estimates as to the value of the work of diffusion can be made

only by comparing diffusion experiments. It is still undecided whether a comparison of the work in practice and a laboratory experiment, which is only a digestion, has any practical value. At any rate a juice prepared by digestion is more suitable for comparison with diffusion juice from the same kind of beets than the press juice. The best comparison between two methods of working is given only by trial runs with two batteries, using the same kind of beets. As such tests can only be conducted with lots of trouble and great expense, on a large scale, it is best in general to base upon figures obtained by the use of small experimental batteries, to regulate the working according to them, and besides that, make it a chief requirement to obtain a good extraction and concentrated juices. The changes through which the materials of which the beets are composed go, by changes in the methods of working the battery, are only little known. The chief constituent, the sugar, apparently suffers no change, even when working hot and slowly, as in many experiments no or only a doubtful increase in invert sugar was found, doubtful in so far as it is uncertain whether the slight increase in invert sugar took place in the battery and came from the raw sugar, or whether the other constituents tend to produce reducing agents. The diffusion juices contain from .05 to .15% of reducing agents, according to the greater or less per cent contained in the beets. Of the albuminous substances a larger part seems to remain in the cossetts when the work is hot than when it is cooler. The per cent of acid in the diffusion juice varies only slightly. The acid reaction is partly due to acids and partly to acid salts of potassium, which either were in the dissolved state in the beets or were dissolved during diffusion. The amount of dissolved pectins and of the soluble calcium and potassium salts increases rapidly with the length of duration of diffusion and

the number of cells. The fertilization and grade of ripeness of the beets has a very great influence upon the solubility of these substances. From beets which were fertilized with too much potassium and Nitrogen a greater quantity of non sugar is dissolved than from beets fertilized with the correct amount of phosphoric acid, not only because these substances are present in greater quantities and are more soluble in the former beets, but also because these beets cannot be extracted as easily, and hence higher temperatures must be used or the diffusion must last longer. Frozen or rotten beets suffer greater changes during diffusion, especially when a long and hot diffusion is used; in this case the percentage of invert sugar, acid and substances containing pectins, rises most.

Changes in the ordinary methods of diffusion have often been suggested and tried without becoming a practical success, or being used for any length of time. In order to reduce the great number of valves in the diffusion batteries used at present, trials were made to carry on the entire diffusion in one body. This mode of working stranded on the impossibility of keeping the juices of different densities from mixing, so that an imperfect extraction was obtained in spite of drawing off thin juices. Then again, it was tried to have the juice flow from the bottom towards the top instead of from the top towards the bottom with the purpose of keeping the cossetts floating and thereby doing away with the stopping up of the lower sieves. But the flow of the juice crowded the cossetts towards the top, thereby stopping up the holes in the upper sieves. Besides that the flow from the top towards the bottom is preferable, as it is then possible to displace the thick juice by the following thinner ones without causing them to mix. In order to coagulate the albuminous substances while still in

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the cells so as to prevent their getting into the juices, it was tried to heat the cossetts just after having been filled into the cell, by steam or very hot juice, to such a temperature at which the albumen coagulates. It is very doubtful whether this method, even in case it were feasible, would have any practical value, as the albumen which coagulates when heated would not create any trouble in later processes. But this method really cannot be executed at all, as heating of the fresh cossetts by means of steam would not only make the juices very much thinner, but would also scald a part of the cossetts so badly that they would get soft and resist the flow of the juice. By means of hot juice one could, even if it were as hot as 212°F only heat a part of the cossetts to a temperature above 160°F and would, at the same time scald a portion of the cossetts.

The fact that the air contained in the cossetts hinders extraction, led to the suggestion of pumping all the air out of the cells before letting in the juice. The profit due to this mode of working is so small that it does not balance the increased expenditure for apparatus and power.

Disturbances in the work of diffusion sometimes require a change in the mode of working. Such disturbances may be due to the conditions of the beets, the inattentiveness of the workmen, or by a shut down in another department .

One of the most difficult problems is to work frozen or rotten beets without slowing the work down too much and getting very poor juices.

Beets which have become frozen through and through in a heavy and lasting frost, will not thaw out in the warm water of the ditches or washing machines. One can be satisfied if the adhering dirt thaws up enough to be washed off. From such beets good cossetts cannot be made.

The ordinary knives will not do at all, and we have to use finger knives of which those with "roof ripper" (Dachrippen) fingers are to be preferred to those with smooth fingers. In this way one gets small cossetts mixed with much pulp which, as such, causes enough trouble in diffusion. Very often the cossetts containing much ice freeze together and form a solid lump as soon as the warm juice is let into the cells and these lumps do not thaw out during the whole time the diffusion lasts. On emptying the cells one therefore, finds besides the normally extracted cossetts also those cossetts which were in the frozen lumps and which have only a small part or none of their sugar extracted. In order to avoid this bad condition as much as possible it is advisable to allow sufficiently warmed juice to enter from the bottom while the cells are being filled. On the other hand, comparatively low temperatures must be used in the rest of the cells, as the cell walls of the beets have already been partly destroyed by the frost and the cossetts, therefore, get soft very easily. Rotten or poorly siloed beets must be treated in a similar way. The temperature must be lowered in accordance with the amount of frozen or spoiled beets in order not to have the pressing too poor.

Self evidently, the extraction of the cossetts under these conditions is very irregular, but of two evils we must chose the lesser, and that in this case is the increased loss in sugar as compared with the use of higher temperatures, which finally would bring the flow of the juice to a standstill, and thereby make the working of such beets an impossibility. The greater loss in sugar is also the smaller evil as compared with a lowering of the quality of the juices, which takes place in a large degree when high temperatures are used in connection with slow work.

The generation of gas during diffusion appears less often in the rapid and hot work used nowadays than it did when slower and cooler work was done. This generation of gas presents itself in the fact that a strong formation of foam appears, especially in the last cell. The foam is caused by gases, composed mostly of hydrogen, which are generated in the cells by fermentation, but experience has taught us that gas is generated mostly when dirty beets are worked, or impure water is used as pressure water.

CHAPTER V.

H A N D L I N G O F T H E P U L P.

The pulp is discharged through the bottom of the cells, and in order that this discharge shall be rapid and regular, the cells must have proper ventilation at the top. The cells discharge in a heap and the pulp flumes must be wide and deep enough to accomodate the entire mass. With the side discharge cells, considerable pulp remains behind; this can be best removed with a strong current of water injected through the bottom screens..

Pulp troughs are generally employed for transporting the exhausted cossettes and are, like beet flumes, the simplest method of transporting on horizontal planes, and the methods of operating them are the same. The troughs should have considerable breadth and depth, but a heavy grade is not necessary, 50 mm., in 1 m., being sufficient. The size of the troughs depend, of course, on the size of the diffusers. The pulp carries more than its own weight of water, and it is usually necessary to float it with the addition of water at the head of the flume. Many factories use air to aid in discharging the pulp from the cells, but it is not always successful. One method of discharging by air, is to pass the air in at the bottom of the cell to thoroughly agitate the pulp, a sliding door in the bottom of the cell is opened at the same time and as soon as the pressure is sufficient, the whole mass is discharged in the direction of the pulp presses.

To elevate the pulp from the flumes, bucket elevators are used, but these present difficulties and do not entirely fill with pulp or drain the water fast enough. These obstacles can be overcome by making the water discharge higher and by placing the elevators directly in the path of the flume. The difficulty with this arrangement, is that the elevator has to work empty for a while and then is

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entirely buried when a cell is dumped. To obviate this, smaller elevators are used and a horizontal arm is made to revolve in such a manner as to catch the pulp, press and raise it from the bin at the same time. These are satisfactory as far as lifting is concerned but do not give a sufficiently dry pulp. Pulp pumps with large pressure pipes are made to work in the same way.

From the lifting devices, the pulp is distributed over the pulp presses. A thorough and constant distribution of pulp is essential, for the presses do not work unless they are entirely filled. The distribution is made by means of a scroll conveyor over the line of presses; the conveyor trough being provided with proper gates over each press. Pulp presses are of all sorts of design, but the essential feature in all of them is that the screen against which the pulp is pressed should be strong and sufficiently porous, and the press water should be properly removed. With all the pulp presses, there is a certain loss of pulp through the screens. In order to prevent this loss, the press water is reconveyed to the pulp flumes.

There is some question as to the value of powerful presses with regulated pressure. With excessive pressure, many of the valuable constituents of the press waters are lost. For direct feeding or souring, the pulp must not be pressed too much, and for these purposes 10% dry substance is considered the desirable amount. If on the contrary the pulp must be dried, it must be pressed as much as possible in order to save in fuel, which is more important than the loss of nutritive material.

The dry substance left in the pulp depends not only on the construction of the presses, but on the properties of the cossettes and the work in the diffusion. Thin crisp cossettes, or those which are warm or hot, press better than those which are thick, spongy, or cold.

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to work in the same way.

From the lifting devices, the pulp is distributed over the
pulp presses. A thorough and constant distribution of pulp is essen-
tial, for the presses do not work unless they are entirely filled.
The distribution is made by means of a swivel conveyor over the line
of presses; the conveyor trough being provided with proper gates over
each press. Pulp presses are of all sorts of design, but the essen-
tial feature in all of them is that the screen against which the pulp
is pressed should be strong and sufficiently porous, and the press
water should be properly removed. With all the pulp presses, there is
a certain loss of pulp through the screens. In order to prevent this
loss, the press water is reconveyed to the pulp flumes.

There is some question as to the value of powerful presses
with regulated pressure. With excessive pressure, many of the valuable
constituents of the press waters are lost. For direct feeding or
sorting, the pulp must not be pressed too much, and for these purposes
10% dry substance is considered the desirable amount. If on the con-
trary the pulp must be dried, it must be pressed as much as possible
in order to save in fuel, which is more important than the loss of
nutritive material.

The dry substance left in the pulp depends not only on the
construction of the presses, but on the properties of the cossettes and
the work in the diffusion. Thin crisp cossettes, or those which are
warm or hot, press better than those which are thick, spongy, or cold.

At the same time, pulp which has been worked hot too long, is harder to press than that which has undergone quick work in the diffusion, the reason for which, is that the cells of superheated pulp thoroughly cook and fill with water. When the pulp is to be dried, it should be handled in the flumes with hot water and pressed thoroughly, but when used for souring it should be worked cold; for deprived of its nutritive substances, it ferments in a few hours and does not keep well in the silos. To increase the dry substance of the pulp and to press it better, very small quantities of milk of lime are sometimes added. This method is apt to cause a larger loss of nutritive material and is detrimental to the feeding value of the pulp.

Pulp Drying. The question as to whether or not it is more advantageous to dry the pulp than to sour it, cannot be discusses here, for the conditions governing the case are too varied to warrant any single conclusion. The advantages are so doubtful that few factories have installed drying processes. A drying process necessitates an increased capital without any apparent rich returns, farmers alone deriving the benefit. When there are no advantages over feeding wet or sour pulp, the factory should not burden itself with a drying process, which can only be of use when the pulp cannot be utilized in the immediate vicinity of the factory.

The pressed pulp is dried directly by contact with gases of combustion, in ovens or drums or by means of steam. The drying by means of gases is done in the so called stage-ovens, in which the pulp comes in contact with the gases heated to 800 to 1000° C. The gases are forced in at the top, after being freed from ashes and odorous gases by passing through combustion chambers and traps. The pulp is agitated and falls from one stage to another until thoroughly dried. The temperature is readily controlled by the air ventilators and the fire, so that the pulp rarely burns or turns brown.

With the drum apparatus, the pulp comes directly in contact with the hot gases by dropping through them. The drum systems vary only in the method of introducing and conducting the gas currents. The drums are usually heated with one oven, and the pulp fed through single openings. It is more difficult to regulate the heat with this system than in using ovens, and the pulp is apt to be, on account of this, more unstable.

The indirect drying with steam is done in double cased housings provided with a number of trays placed one above another. Steam pipes provided with shovels and rakes are revolved in the trays to thoroughly mix the pulp. The pulp must be hashed up after pressing, in order to insure thorough drying. The water vapor is drawn off, thus drawing some air through the bottom of the apparatus and aiding the evaporation. The temperature, during the operation, is about 100° C., and even with slow work does not exceed that very much. The pulp never browns by this method and maintains its natural color and porous structure, while the fire dried pulp is somewhat dark and glassy. The steam drying requires less care and is simpler than the fire process, but cannot be forced. The costs are higher on account of fuel, though cheaper coal can be used for the work. The original cost of the steam process is higher but the repairs of the fire process make up the difference. The advantages of the former are in giving a superior product, and it is most generally in use. With the direct drying, it is possible to use as much as 80% of the total heat value of the fuel, though such intensive work is apt to give poor pulp.

The changes which occur in the pulp while drying are not thoroughly understood. As long as the pulp is uninjured, that from the fire process seems to be the most durable. The pulp dried by steam is really the best and has the advantage of swelling rapidly in cold water. The pulp dried in the fire process has a somewhat higher dry substance on account of the wet pulp absorbing some flue ashes.

The quantity of dried pulp from 100 parts of beets, varies from 5.5 to 6.5% according to the sugar content, the extent of the digestion, the pressing, and subsequent losses. In the fire process the losses are somewhat greater, but do not exceed 2% of the entire dry matter.

The durability of the dried pulp is proportionate to the drying, and must be stored dry and well ventilated. In damp storage, moulds are apt to grow, particularly when there is any sugar left in the pulp. Material dried at a high temperature is less apt to absorb water than porous, steam-dried pulp.

Before drying, pulp is often soaked in hot dilute molasses. 4 to 5 parts of molasses being added to 100 parts of fresh pulp. The molasses is readily absorbed, and the drying occurs in the usual way. Caramel is apt to form and cannot be prevented in the fire process. In the steam process, molasses is added after drying and is quickly and easily absorbed, giving a dry permanent feed.

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THE PURIFYING AND PRE-HEATING OF THE DIFFUSION JUICE.

The raw juice obtained by diffusion is a yellowish, turbid liquid which becomes dark rapidly when exposed to the air, so that after a few minutes it becomes black. The juice contains nearly all substances which are dissolved in the beet and such which are dissolved during diffusion. Usually the density of the raw juice varies between 12 - 15 Brix and contains from 10 - 13% of sugar. The larger part of the organic-non-sugar constituents are unknown; for every 100 parts of sugar there are about 2 - 2-1/2 parts albuminoids, 2-1/2 - 3 parts other nitrogenous substances, 1-1/2 parts reducing agents, 1 part Pentosan and 0.4 - 0.8 parts Oxalic acid present. The inorganic constituents are mostly Potassium, Sodium, Calcium, Magnesium, Phosphoric Acid, Sulphuric Acid, Chlorine together with other bases and acids in very small quantities. The reaction of raw juice is always acid and amounts to about 2% normal acid.

The object of purifying of the diffusion juice is to remove all of the pulp and fibres, which find their way through the sieves, before "separation".

The removal of all pulp and fibre before separation is of great importance and should never be neglected. These substances act harmfully by depositing themselves on the heating surfaces of the pre-heaters, thereby decreasing their efficiency, and alsc, in case they reach the separator, they are partially decomposed by the lime and are converted into slimy substances a part of which remain in the juice as impurities, while the rest are precipitated during separation as a slimy mass which slows down the filtration greatly if present in any appreciable quantity.

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For the mechanical filtration of the diffusion juice we use pulp or cossett catchers, of which there are a great number of types. In all of them the filtration takes place through a fine metallic sieve, which is kept free from fibres by brushes or scrapers. Arrangements are made so that the scraped off fibres can be removed easily. These filters are the more efficient the finer the sieve is but then the filtering surface has to be larger and the scraping arrangements the more perfect.

In placing the pulp catcher between the pre-heater and the battery, arrangements must be made to pass the pulp, which is filtered out, back to the diffusion cells, as only in this way the juice which passes out with it can be easily extracted. The pulp catcher should be emptied into a cell half full of fresh cossetts and then the filling of the cell with fresh cossetts may be completed. This method must be followed strictly, so that the small pieces of pulp and fibres get scattered between the good cossetts and do not hinder the flow of the juice, whereas when emptied upon the lower sieve they stop up the holes and cause bad pressing.

The fact that albuminous substances are coagulated by heating the juice, especially the pressed juice, has led to the construction of so called albumen-catchers through which the diffusion juice, heated to 176°F, is passed in order to free it from albumen. The whole idea is erroneous. By heating the raw juice only a very small quantity of albumen can be separated and that is in such a form that it cannot be filtered. Of the small quantity of albumen present in the raw juice (about 0.2 - 0.3%) only about 10%, i.e. 1.02 - 0.03% of the juice can be coagulated by heat. Such a quantity is hardly worth considering and certainly does not warrant the establishment of an expensive plant.

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Then too, there is no object in filtering off the coagulated albumen before separation, as it is not then acted upon by lime and can be separated in the filter presses. If, as is maintained, good results are obtained by using albumen catchers, the fact should be attributed to the removal of the pulp. If the albumen catchers are very large so that the juice is not in constant motion at all points, their action may become very harmful due to the micro-organisms in the juices.

For purifying the diffusion juice the use of sulphurous acid, baryte and the electric current have been proposed, the latter in connection with soluble electrodes and electrodialysis. These all cause the precipitation of organic and coloring matters, but as nearly all these non sugars are precipitated by lime it seems unnecessary to substitute more expensive materials for cheap lime, the superiority of which, if it exists at all, is in no direct ratio with the increased cost.

THE PRE-HEATING OF THE DIFFUSION JUICE:

In the measuring tanks the diffusion juices have a very variable temperature. It depends upon the mode of working and the temperature of the fresh cossetts, and might therefore, vary from a little above 32° to 104°F - in most cases it lies between 77° and 95°F. In order to heat the juice to the temperature necessary for separation it is passed through tube heaters which are made either horizontal or vertical, or open or closed.

By pre-heating the juice those substances which are coagulated by heat and resist the decomposing action of the lime are separated better than when in the insoluble state. A part of these substances are albumenoids, but the greater part are substances which do not contain nitrogen.

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In general the open preheaters are preferred because they can be cleaned without being cut out. The disadvantages of these heaters are their low efficiency and the fact that the surface of the liquid is exposed to the air. Their efficiency can be raised by improving the circulation of the juice by means of pumps or scrolls and also by the use of mechanical devices for continuously cleaning the tubes.

The closed preheaters are more appropriate than the open ones. In them the velocity of the juice is increased by having to pass through a number of sets of heating tubes. In such preheaters the deposits formed on the tubes are slight and therefore their action is quite regular.

The best preheating plant consists of a battery of small preheaters which contain long tubes of small diameter and in which the velocity of the juice is kept at at least 3 - 6 ft. per second by means of special pumps. Although when the juice flows at this velocity the deposit on the heating tubes forms very slowly, each separate heater shouod be so provided with valves that it can be cut out and cleaned without interfering in the least with the rest of the work. The transfer of heat in these preheaters is very much greater than in the open ones and therefore their heating surface may be smaller or they may be heated with low pressure vapors.

Preheaters of too large a volume should not be used as the juice is kept in them for an unnecessary length of time, and too long a heating of the juice always has bad consequences, such as a noticeable inversion of the sugar. Even when acid reactions have no effect upon the juice as long as the temperatures remain normal, an inversion always sets in when the juice is kept at a temperature of 194°F or over for

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any length of time. In order to prevent such harmful consequences of the acidity about 0.2% of milk of lime is sometimes added to the raw juice in order to make it slightly alkaline before entering the preheater. The addition of the milk of lime also acts usefully by reducing the deposits upon the heating tubes. But it was often noticed that, due to the addition of the lime the filter presses ran slower so that the "pre-separation" which is really seldom necessary, is rarely used.

Most factories have two preheaters or two preheating systems, of which the first is heated by the vapors from the last body of the Quadruple Effect, and therefore heats the juice without expense up to 113° or 131° F while the second is heated with vapors from the first body in which the juice is heated to the temperature necessary for separation - at least to 158°F, better to 176° or 185°F.

As at the beginning of the campaign no vapors from the evaporators are at hand, every heater must be so connected up that it can be heated with boiler steam or exhaust steam from the engines. Especially when beginning work, when the juices, apparatus and pipes are all cold arrangements must be so that the juices can be heated to the correct temperatures, which should be a little higher than usual. When the juices are insufficiently heated the work suffers greatly.

Every preheater must be so arranged that it can be cut out when it has to be cleaned or becomes leaky. In order to discover leaks the condensed water should be tested regularly for sugar. Losses of sugar are more likely to occur in the heater than in the evaporators for in the former the pressure is in the part of the apparatus containing the juice is usually higher than the pressure in the heating tubes, while in the latter the reverse is the case.

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CHAPTER VII.

DEFECATION.

When the heated raw juice is treated with lime it undergoes a defecation. Heretofore Defecation and Saturation was used in all factories, and is still used in many today. In this process the saturation with carbonic acid begins as soon as lime, in the form of milk of lime, has been added to the juice. A large amount of lime is thus changed into calcium carbonate before it has a chance to act on the juice and therefore a very much greater amount of lime is used in the process than when the defecation is conducted in special defecating pans.

There is a distinction made between the milk of lime or "wet defecation" and the "dry defecation". In both processes a part of the lime is dissolved but the greater part remains suspended in the juice. The solubility of lime in sugar solutions depends upon the per cent of sugar they contained and the temperatures. At ordinary temperatures so much lime is dossolved in the thin juice, after a sufficient interval, that the ratio between sugar and dissolved lime is such that the Mono-saccharat can be considered in solution. The higher the temperature of the juice the less lime is dissolved, so that at the ordinary temperatures of defecation (abcut 176°F) only about 0.25 - 0.35 parts of lime are dissolved in 100 parts of juice containing from 10 - 12% of sugar. The wet, or milk of lime defecation is conducted by adding thick milk of lime, of about 20° Bé, to the raw juice. The defecating pan used for this purpose is equipped with an ordinary stirring device in order to get a good mixture in a short time. If the saturation tank is also used for defecation, the mixture of the juice and the milk

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of lime is made by passing the saturation gas through them.

In small factories milk of lime is often made by slacking the lime in flat slacking pans. It is much more appropriate to use drums constructed on the principle of the bone-black washers, as in these the slacking is much more perfect and takes place without annoying the workmen. For slacking it is best to use the last sweet water from the presses. When this is not present in sufficient quantities, cold well water should not be used, but pure condensed water from the evaporators or thin juice.

In order to remove the soluble substances present in the lime slacking the lime with much water was suggested. The thin milk of lime settles to the bottom and the water with the dissolved impurities can be drained off. Most limes contain few salts soluble in water, excepting the alkalies, and those constituents of lime which dissolve with difficulty, calcium silicate and clay for instance, can never be removed in the above manner as they are more soluble in juices than in water. In consequence no advantage can be ascribed to this process; the work becomes complicated and the advantage of using freshly slacked lime is lost. The longer milk of lime stands the less vigorous will be its action on the juice. This is probably due to the fact that when standing the lime combines with a greater amount of water. Slacked lime that has been slacked for any length of time defecates the juice slowly and imperfectly.

The dry defecation is now nearly always conducted by adding lime, in pieces about as large as a fist, to the diffusion juice heated to at least 149° to 158°F. The addition of lime in the pulverized condition has, due to the increased work and cost of grinding, proved to be unnecessary and unprofitable.

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When the burned lime is put into the hot juice it immediately begins to slack. As its combination with water is always accompanied by a generation of heat (1lb. upon slacking gives off 272 B.T.U.) and a local overheating of the juice would produce harmful decomposition. More attention should be paid to the construction of dry defecating pans to avoid such injurious effects, especially in handling lime that slacks easily and vigorously.

The old way of conducting dry defecation by hanging a basket filled with pieces of lime into the juice is not commendable. A correct dry defecation plant should fulfill the following conditions:

1. The lime must be in a flat layer when it comes in contact with the juice.
2. The juice and the lime must be kept in motion constantly.
3. The pan must be easily emptied of residual stones and grit.

These conditions are fulfilled when the lime is spread on a stationary or rotary sieve while the juice is kept moving by a stirring device which has arms above and below the sieve. The tank must also be provided with man holes for cleaning.

The dry as well as the wet defecation can be made continuous by having the juice enter the defecating pan from below and flow off, through an overflow, to the saturation pan, and every time a measuring tank full of juice flows through the pan the necessary amount of lime is added. A valve must be at the bottom of the pan so that it can be completely emptied for cleaning. How often this has to be done depends entirely upon the nature of the lime used.

The method of defecation to be preferred depends upon conditions which have nothing to do with the action of the lime, for as far as the purifying of the juice goes no difference can be found between the two methods.

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Any differences would moreover be theoretically impossible. The dry defecation is most appropriately used when little sweet water is available from the filter presses and the kiln is situated near the defecating pan, so that the lime can be handled inexpensively. The wet defecation is best for factories which sweeten off the filter presses well, and where the kilns are so far away that the lime is handled best by pumping as milk of lime.

To the credit of dry defecation, should be stated the fact that the action of lime is quicker and more vigorous than in the wet defecation, so that in the former, a smaller quantity of lime is necessary to purify a given amount of juice than in the latter. But juice undergoing dry defecation contains a greater amount of lime in the dissolved state than juice defecated by means of milk of lime. This fact accounts for a more rapid saturation and gives a better absorption of the saturation gas. As it is still questionable whether a thorough sweetening off of the filter presses is profitable, and the sweetening water is never sufficient to slack all the lime unless the presses are sweetened off very thoroughly, fresh water is always added at the slacker. There is good reason to fear passing the purified thin juice back to the slacker. In consequence the coal consumption in factories using wet defecation is higher, other conditions being equal, than in factories using dry defecation. The fact that the juice itself is heated a number of degrees by the slacking of the lime during dry defecation, while the sweet water cools off in evaporating should also be mentioned. In general therefore, unless special conditions occur, the dry defecation is preferable to the wet.

It is notable that in a number of experiments made with dry defecation, it was found that the losses in sugar were greater and the purity lower than in wet defecation; but those results seem to be due to

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erroneous methods of handling the dry defecation process, which causes the formation of insoluble saccharate which is not broken up in saturation. The gray tint of sugar which is blamed to dry defecation is due to entirely different causes. Insoluble saccharate can be formed in the wet defecation as well as in the dry, as the insoluble lime salts formed during defecation have a tendency to pull down small quantities of soluble lime salts, such as saccharate upon precipitating. Insoluble saccharate is again precipitated out of all defecated juices if they are heated too highly after defecation. Naturally more is precipitated from juices undergoing wet defecation, as the former have more lime dissolved in them. Hence care must be taken, especially after dry defecation, that the juices are not reheated before they are entirely saturated, and that no local overheating takes place. Therefore the temperature of the raw juice must be high enough not to need any reheating before saturation is completed.

The action of the lime on the raw juice is chemical as well as mechanical in nateure. The lime acts chemically by precipitating and decomposing the non sugars and mechanically, by carrying down substances suspended in the juice when precipitating. Suspended in the raw juice are fine beet fibres which are not caught in the pulp catchers, and all substances which are not coagulated by heating; also a great amount of micro-organisms and ferments which make themselves noticeable by an inversion of the sugar and a souring of the juices when they are allowed to stand for any length of time. All these substances are carried down by the precipitates. The precipitate so formed easily settles on the bottom while the remaining juice is light yellow, clear and perfectly sterilized. A separation of scum such as in the pressed juice from the beets is not possible with diffusion juice.

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The chemical action of the lime on the non sugars takes place in such a way that the lime first neutralizes the acids and acid salts and forms insoluble salts with a part of the organic and inorganic acids such as oxalic and Phosphoric acids. Also all substances which are insoluble in alkaline lime solutions are precipitated. The alkalies, such as ammonia and the organic bases, which are combined with the precipitated acids, are not free and act together with the surplus lime on the remaining non sugars. The alkalies as the strongest of the bases immediately combine with the acids which form no insoluble compounds with lime, if such acids are present, while ammonia and the organic bases remain uncombined in the juice.

Many of the organic non sugars which remain in solution are more or less decomposed in alkaline solutions, especially the invert sugars, amides, amids and albuminoids. All these substances which, though not acid in character give off acids in hot alkaline solutions, while nitrogen ous substances are decomposed into ammonia and organic bases.

The acids which form soluble salts with lime, combine first with the free alkalies which may be present only after they have been burned with lime.

Hence, the lime acts in two ways during separation, first it tends to purify the juice by precipitating non sugars, second, it changes the nature of some non sugars without removing an appreciable amount of them. Both these actions are advantageous in the after work, the second no less so than the first. The amount of non sugars that are precipitated is less than is generally supposed. By the defecation and the saturation the purity of the juices is only increased from 4 - 6%. Of the 12 - 15 parts of non sugars contained in 100 parts of solid matter in the juice only one quarter or at most one third are precipitated.

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The decomposing action of the lime upon the substances remaining in solution is very often undervalued. By decomposition these substances lose many of their characteristic properties which in the future working especially the crystallization, would act harmfully.

The alkalies present in the raw juices are not removed by defecation. A very small portion is carried down by the lime precipitate during saturation, but by far the greater portion remain, combined with acids, or as free alkalies in solution, (after saturation as salts of carbonic and sulphurous acids) and finally reappear in the fillmass.

The amount of free alkalies present in the defecated juice depends entirely upon the acids with which they are combined in the raw juice. If the raw juice contains many acids that combine to form insoluble compounds with lime, then the acids remaining in solution after saturation do not suffice to bind the alkalies, of which a large portion thereof remain free and act decomposingly upon the sugars during defecation as well as in later processes. Juices which after saturation still contain alkalies combined with carbonic acid, have a reduction of alkalinity during evaporation which is in no way harmful. Only traces of calcium salts are found in them.

If the greater part of the acids in the raw juice combine to form soluble salts with the lime, then the alkalies set free during defecation will combine with these acids during saturation, or even during defecation, and lime will be set free. Free alkalies or alkalies combined with carbonic acid are then no longer present in such juices and the alkalinity which is then left in the juices, is not due to alkalies but to ammonia, organic bases or lime. If in juices of this constituency the decomposition of the invert sugar, the amides and the albuminoids does not take place during defecation, they may become neutral or sour later on. To avoid this, the saturation of the thin juice

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should be conducted just far enough to leave some free lime present, so that it can bring the decomposition to an end and bind the acids, which become free during the working of the juices. Such juices are always rich in lime salts.

The decomposition of the non-sugars whichare broken up by lime, should be carried as far as possible during defecation. It is impossible to completely finish the decomposition during defecation, as some of the substances are decomposed slowly, under the conditions present during defecation. It is not advisable to continue the action too long, or to use high temperatures, because of the danger of dissolving non-sugars and precipitates. Besides the conditions during evaporation are so favorable for further decomposition, that it is not advisable to conduct the defecation other than for a light saturation.

For normal beets, the best temperatures for defecation are between 158° and 185° F. Cold defecation has also been tried and recommended, with the assumption that at higher temperatures the lime would again decompose some of the precipitated substances and carry them into solution. There is nothing to prove that there is any appreciable difference between hot and cold defecation, when the juices undergoing cold defecation are heated after filtration and the action of the lime is kept within practical limits. Many experiments even show hot defecated juices to be superior to those treated cold, besides cold defecation cannot be used at all in practice, as the juices obtained by it cannot be filtered rapidly, even when substances like "Tripoli" are added to the precipitate.

In general, it is not advisable to use temperatures above 194 or even 212° F during defecation. Higher temperatures have a favorable action only when the beets are poor and contain much invert sugar, and other substances that are decomposed by lime. But under such conditions

the juices should not be boiled for any length of time in order to avoid the redissolving of the precipitates. The notion that boiled defecated juices are more easily filtered after saturation is incorrect; boiled juices are more difficult to saturate, and yield lime cake high in sugar.

The duration of the defecation must be kept within definite limits. For low temperatures of from 158 to 176° F., it should last about 15 minutes, while for higher temperatures from 5 to 10 minutes are sufficient.

The quantity of lime that is necessary for defecation varies between wide limits in different factories. For the neutralization of the raw juice, and the precipitation of all substances precipitated by lime, only 0.15 - 0.20% of lime is necessary. A true separation, i.e. a quickly settling precipitate and a clear juice is not obtained until 0.50 to 0.75% of lime have been added. But even this amount of lime is insufficient for practical conditions, as the juices obtained in this manner can only be filtered slowly, even after saturation. The filtering after saturation is not satisfactory until 1.50 to 2.00% of lime is added. In many factories more lime than this is used, the minimum being from 2.50 to 3.00%.

Lime is added to the raw juice with the idea that, the more lime that is used, the greater the purification of the juices will be. By using more lime, we certainly get lighter colored juices, containing somewhat less lime salts; but a difference in the purity is never found when either large or small quantities of lime are used. The decomposition of the salts, decomposable by lime, will not take place more rapidly or vigorously because of an excess of lime, for it is only the dissolved lime that acts, and this amount does not depend upon the lime added but upon the sugar content and the temperature alone. For this

reason the improvements due to large amounts of lime never show during defecation, and do not become apparent until saturation. Whether these advantages are important enough to counter balance the numerous difficulties connected with the use of an excess of lime, depends on each individual case. Larger quantities of lime not only increase the costs because of the excess lime and carbonic acid, but increase as well the quantity of lime cake and the sugar losses connected therewith, and require more filter presses and a larger lime kiln. Where very light colored juices are required, for instance in factories making rock candy or granulated sugar, the use of large quantities of lime seems to be justified, but this is hardly the case in factories which produce raw sugar.

The milk of lime which is added to the raw juice should have a uniform density 20° Be', in order to prevent variations in the amounts of lime added. For dry defecation the lime, after having been broken into pieces of uniform size, should be weighed or measured. Although at first sight, weighing would seem to be the more accurate method, measuring is to be preferred, so that the effect of poorly burned (and therefore heavier lime) causes less error than when the material is weighed.

The lime should be used as soon as possible after burning, as it is then slacked more readily and acts quicker. If after storing a length of time the lime starts to drop apart, its action has been reduced, owing to the formation of calcium hydrate and calcium carbonate, and larger amounts must consequently be used. If the lime is burned by combustibles in the kiln, the ashes should be separated from the lime as well as possible, in order to avoid their getting into the juices and decreasing their purity.

reason the improvements due to large amounts of lime never show during
defecation, and do not become apparent until saturation. Whether these
advantages are important enough to counter balance the numerous difficulties connected with the use of an excess of lime, depends on each individual case. Lerrow maintains that lime not only increases the coefficient of the organic and colloidal matter, but increases as well the quantity of lime salts which otherwise would be precipitated therewith, and requires more filter press and slower time rate. Where very light colored juices are required, for instance in factories making sugar candy or granulated sugar, the use of large quantities of lime seems to be justified, but this is hardly the case in factories which produce raw sugar.

The pH of the water introduced to the raw juice should have a uniform density 200 Be'. In order to prevent variations in the amounts of lime added. For dry defecation the lime after having been broken into pieces of uniform size, should be weighed or measured. Although at first sight, weighing seems to be the more accurate method, measuring is to be preferred, so that the effect of poorly burned (and therefore heavier dense) cores may not be more than when the material is weighed.

The lime should be used as soon as possible after burning, as it is then slacked readily and acts quicker. If after storing a length of time a thick crust appears to have formed, it can safely be discarded. Owing to the formation of calcium hydrate and calcium carbonate, and large amounts must consequently be used. If the lime is burned by combustion in the kiln, the cores should be separated from the lime as well as possible, in order to avoid their getting into the juices and decreasing their purity.

CHAPTER VIII.

S A T U R A T I O N .

In order to precipitate the lime out of the defecated juice, use is made of the carbonic acid gas produced in the lime kiln. In the past, sugar makers were inclined to think that carbonic acid gas when passed into the limed juice, would tend to dissolve the precipitated substances. These conclusions were based upon the fact that oversaturated juices, that is juices which have absorbed enough gas to make them neutral, or even give them a light acid reaction, assume a blackish tint. Consequently, methods were advocated in which the juices were saturated after the precipitate, which had formed during defecation, had been filtered off. These methods proved unsatisfactory, due to the reasons which will be explained later.

Nowadays, the defecated juice is almost universally saturated while still containing the precipitated substances and the undissolved lime. The defecated juice flows from the defecating pan into the saturation tank, which in places where the "Defecation Saturation" Process is used, takes the place of the defecating pan. The saturation tanks are round or rectangular, open or closed vessels and are often made of considerable height. In the lower portion of the tanks, are devices for distributing the carbonic acid gas and open or closed coils for steam heating. The simplest and commonest means of distributing the carbonic acid gas is by the use of perforated pipes. The gas is thus destributed fairly well but the holes get stopped up easily, especially when they are small. Cleaning the holes while the pipes are still in the tank is a disagreeable and dangerous task for the workmen, so arrangements are made by which it is possible to extract the perforated pipes, which become scaled, and insert new ones in their places. In order to do away with the work of cleaning entirely, distrib-

CHAPTER VII

SATURATION

uting boxes are used. These boxes are open below and have their lower edge indented so as to give an even distribution of the saturation gas. Sometimes the side walls of these boxes are perforated.

Even with distributing arrangements it is only possible to utilize one-half or at most two-thirds of the carbonic acid gas delivered to the pipes, the absorbtion being the greater as the height of the juice in the tank is increased. The longer the path that the bubbles take through the juice the better will be the absorbtion of the carbonic acid gas. This explains the advantage of having a great height of juice in the tank. The utilization of the carbonic acid gas is also better the smaller the bubbles, and the more intimate the mixture of gas and juice. Turbine or injector-like emission arrangements, as well as stirrers which keep the juice in motion and split up the bubbles, have proven very satisfactory. To utilize the carbonic acid gas in the departing gases, the introduction of finely atomized juice has been suggested, but this idea though good in itself, is impossible of realization, because the juice atomizers get stopped up constantly. There is usually no need of a complete utilization of the carbonic acid gas, as all factories which burn their own lime have plenty of it to spare.

Closed heating coils for heating the limed juice in the saturation tanks cannot be used as they quickly become inefficient due to scaling with lime. Hence, if it is found necessary to heat the juices in tanks, open heating tubes should be used. In general, heating the juice before saturation should be avoided, though it is advantageous to heat the saturated juices to a high temperature. In order to avoid the thinning of the juice which occurs when open heating tubes are used, and to make it possible to use exhaust steam from the evaporators, it is advisable to pump the saturated juice through closed tube heaters, heated with steam of at least 212°F. Deposits of lime on the heating

tubes are not apt to occur if the juice is allowed to enter the heater from above and flow out at the bottom.

The height of the juice in the saturation tanks must be, as stated above, as great as possible in order to get a good utilization of gas, but naturally should not be such that the gas pump cannot overcome the counter pressure with ease. The foaming space too, should be as high as possible, at least 10 ft., so that the foam formed during saturation can find plenty of room. A high foaming space is the best remedy for foaming-over, the higher the space the fewer means are necessary for preventing the difficulty. Foam is destroyed by the injection of steam or the addition of fat. Steam foam-killers use much live steam and thin the juice. The addition of fats and oils is expensive and besides, unsuitable brands lower the quality of the juices or produce difficulties in the filter presses, causing low filtration when the fats are not easily saponifiable. Still, the use of small quantities of oil or fat cannot readily be avoided. In such cases, oils with a high viscosity should be used such as castor oil, tallow etc., because less of them is required. Arrangements should always be made by which the quantities of oil added can be controlled. For this purpose a large tank should be provided with a gauge glass, from which the oil can be pressed or pumped, through pipes, to the saturation tanks. The pressure in the tank can be obtained by making connections with the gas-pump.

The saturation gas, deprived of most of its carbonic acid in passing from the tanks, is discharged through pipes of large diameter, in which any foam which may have been carried along, has a chance to collect. Sometimes these vapor pipes are provided with an enlarged section which acts as a juice catcher. When one vapor pipe is used for a number of tanks, arrangements should be made so that the foam from

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any one tank cannot pass over into another, in order to prevent unsaturated juice from getting into a tank already saturated, which would result in bad filtration and a smearing of the presses. In order to test the discharged gases for the amount of carbonic acid they contain, a gas collector should be connected to the vapor pipe.

The saturation gas is nearly always pumped into the juice. The pumps used for this should never be belt driven, and should always be provided with their own steam cylinder, so that the pump capacity can be changed at any time, in accordance with the amount of gas that is required. Steam injectors which are sometimes used to force the gas into the juice are not to be recommended, on account of the expense of the steam, the overheating and dilution of the juices; they are only useful in cases of emergency when repairs have to be made on the pumps.

The saturation of the defecated juice requires great attention from the carbonation man, for a poorly conducted or a slow saturation reduces the quality of the juices and often causes aggravating difficulties in the running of the filter presses. Hence, the position of the man in charge of the saturation is just as responsible as that of the man in charge of the diffusion battery, especially when the juices are in a bad condition from the start. If a special defecating station is present, the workman should always assure himself that the juice is well defecated before he turns on the saturation gas. When saturation is complete a sample should separate quickly into a precipitate and a clear filtrate. In case dry defecation is used, the filtrate should have an alkalinity of from .025 - .032, according to the temperature, though somewhat less is satisfactory in defecation.

As soon as the saturation tank becomes filled to the correct height, the gas valve should be opened gradually, in order to avert

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As soon as the saturation is properly effected to the correct height, the gas valve should be closed gradually. In order to avert

violent foaming. For the gas pump to work uninterruptedly and the utilization of the gas to be as high as possible, the valves on each of the tanks should be opened in such a manner that the tank in which the saturation is furthest advanced and in which the juice foams least shall get the most gas. Working in this way all tanks should be filled to the same level, or on account of the differences in pressure, due to the head, one tank would obtain more gas than others, and the saturation would take place very unevenly, destroying the regular sequence which is so desirable for watching and regulating the saturation.

While saturating, the workman takes numerous samples and watches the settling of the precipitate. When open tanks are used, the sample is taken out by means of a ladle with a long handle, or by means of a small pump. From closed tanks the sample is taken out of a faucet near the bottom. Well trained workmen can saturate quite accurately by the appearance of these samples. In some factories the workmen saturate only by the sound made by the rushing gas. The conduct of the juices during saturation is, as far as outside appearances go, as follows:--

Soon after the gas is turned on the juice begins to thicken, proportionately so in regard to the amount of sugar it contains. A sample will show that the precipitate is of a gelatinous nature and will not settle. The consequences of this gelatinous constituency are foaming at the beginning of the saturation and a rumbling noise made by the gas. A filtration of the juice at this time is absolutely impossible and when it accidently gets into the presses, the cloths become smeared at once. On continuing to pass the gas through the juice its gelatinous constituency slowly disappears, the gas issues more uniformly and in smaller bubbles, the juice again becomes less viscous, the foaming finally stops, and a liquor is obtained in which the precipitate settles rapidly and is easily filtered off.

During the saturation the alkalinity of the juice naturally decreases, but not in a uniform manner. At first the alkalinity decreases rapidly from 0.35 to about 0.15 - 0.18. At this point it remains practically unchanged for quite a while and nearly as much lime dissolves in the juice as is precipitated by the carbonic acid gas. When finally the last lime becomes dissolved, the alkalinity sinks rapidly from 0.15 - 0.18 to 0.07 - 0.10; this amount is found to yield the best constituency and filters best with juices of the 1st saturation. Therefore, the workmen must watch the hot portion of the saturation with particular care, in order not to oversaturate.

In all factories in which chemical supervision is established every tank is titrated when the saturation is thought to be complete, in order to be certain that juices of correct and uniform alkalinity are sent to the presses. Hence, the precipitate test is only used for obtaining a preliminary clue as to the advancement of the saturation. The appropriate degree of the final alkalinity varies with the constituency of the juice from 0.07 - 0.10% lime, (Phenolphtalein test) or 0.09 - 0.12% lime (Rosolic acid test).

The chemical reactions during saturation have not yet been made quite clear. Upon injecting the carbonic acid gas, not only calcium carbonate is formed but also a combination of calcium carbonate, saccharate and possibly calcium hydrate. This combination forms a gelatinous precipitate which imprisons large amounts of sugar in the form of insoluble saccharate. The more this precipitate is formed, the thicker the juice, the colder the saturation is conducted and the higher the percentage of sugar in the cake. Besides these phenomena, a number of other unknown actions are to be noted in connection with the constituency and amount of these combinations. By heating and thinning and by treating continuously with carbonic acid gas the com-

bination is partly decomposed. During saturation the amount of this combination constantly decreases, until the alkalinity is brought to the correct point, when nothing of it is left. In some cases, though, the decomposition is retarded so that small amounts of the double salts remain in the precipitate and cause an increased loss in sugar.

Besides, the action of the saturation which is directly connected with the neutralization of the lime, some secondary effects are produced, which are partly of a favorable and partly of a harmful nature. A favorable action is the precipitation of a part of the lime salts which are soluble in alkaline solutions, together with the calcium carbonate. This precipitation can only be due to the formation of double salts, for the more these lime salts are thrown down the more lime must be used for defecation and the more calcium carbonate is formed and precipitated in the juice.

Another effect of the saturation is the carrying down, with calcium carbonate, of the light, slimy, voluminous, organic and inorganic precipitates formed during defecation. The precipitation of the calcium carbonate does not happen instantaneously, but takes some time. The precipitate forms more easily and rapidly when a nucleus of growth is present, such as the impurities floating in the juice. These light particles which, as such, can be filtered off only slowly and with difficulty are partially or totally covered by a shell of calcium carbonate, and thereby loose their slimy or gelatinous consistency to such an extent that they can be easily filtered. Saturated juices can therefore be filtered more readily than defecated juices, even when calcium carbonate, diatomatious earth, etc., are added to them, as the mixing cannot take the place of the mechanical precipitation during saturation.

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favorable action is the precipitation of a part of the lime salts

an appreciable amount of sugar in the precipitate in the form of saccharate.

Hence, the presence of insoluble saccharate in the precipitate can be due to three causes; 1st., the precipitation of saccharate during defecation, caused by local overheating of the juice or by too high a heating after the addition of lime. 2nd., the fact that a part of the precipitated saccharate formed during the early part of saturation remains undissolved, even after the saturation is ended, and 3rd., the fact that saccharate may be precipitated together with the insoluble lime salts during both defecation and saturation. The quantities of saccharate which are precipitated due to any of these causes are, in general, very small, but may become quite appreciable under unfavorable conditions, and all three causes may act at the same time. The effect of such saccharate formations are high percentages of sugar in the lime cake which cannot be materially decreased by sweetening off, and a decrease in the purities of the juices.

If a comparatively large amount of saccharate is precipitated and the filter presses cannot be well sweetened off, the condition can be remedied by lowering the alkalinity of the juice as much as possible. But as insoluble saccharate is decomposed with certainty only in juices free from calcium hydrate, it is sometimes advisable to over-saturate the juice in case the presses cannot be successfully sweetened off. The juice and precipitate then assume a dark, nearly black, color, the precipitate does not settle well and consequently the juice remains turbid; such over-saturated juices cannot be filtered at once, but if a little milk of lime or freshly defecated juice is added to it so that the alkalinity again rises to at least 0.10 the appearance of the mixture will be the same as that of juice correctly saturated to the same alkalinity.

Without doubt over-saturation produces inferior juices, due to the action of the carbonic acid gas. Juices free from calcium hydrate, when neutral of slightly acid, redissolve organic-non-sugars as well as precipitated lime salts and coloring matter. Whether or not all the dissolved non-sugars in the oversaturated juice are again precipitated upon the addition of milk of lime or freshly defecated juice, has never been shown, though it seems very probable that such is the case, as no difference can be detected, in the subsequent working, between the behavior or such juices and those which have been correctly saturated; unless the former are too highly over-saturated and later have so much lime added to them that the mixture has an alkalinity above 0.10, and has to be saturated again for a short time.

The saturation has been described here as it is usually conducted, namely, the saturation of each tank separately. A continuous working has certain advantages and many experiments have been made in this direction. The experiments made with continuous saturation were conducted in such a way that the defecated juices, together with the saturation gas, were forced through coils of pipe so as to secure a better utilization of the gas by creating a more intimate mixing of juice and gas. All attempts have failed because of the impossibility of obtaining a uniform alkalinity. The juices, on leaving the pipe were not saturated enough at one time, and were over-saturated at other movements. In these experiments the fact was overlooked, that, in order to produce a uniform alkalinity, large quantities of juice must be worked at once, as the variations in the percentage of carbonic acid in the gas, as well as the amount of lime in the juice, are quite large. The best results were obtained with quite a simple continuous saturation, which is conducted as follows:---

The defecated juice is allowed to flow into an ordinary

saturation tank into which the necessary amount of saturation gas is injected. From this tank the partially saturated juice flows into a second tank, through a riser leading from the bottom of the first tank to the top of the second, in which it is treated with enough gas to bring the alkalinity down to the required point. For the second tank, or better for a third tank, into which the second overflows, a preheater may be substituted. By careful regulation of the flow of the juice and the gas, a very good and uniform saturation may be obtained.

Disturbances during saturation manifest themselves most often by slow working. For this there are many causes. It is self evident that a gas containing sufficient carbon dioxide is the first requirement for rapid saturation. From such a gas, not only a higher absolute amount but also a higher percentage of gas is absorbed, by the juice, than from a poor gas. The required amount of saturation gas must also be delivered to the juice. If the gas pump is too small or works badly, the saturation will always be defective. The size of the pump cylinder should therefore be made large enough s that under ordinary conditions only a small number of revolutions of the pumps are necessary and possible defects, such as leaky pistons or valves, poor throttling due to high piston speed, can be overcome. The amount of gas and the capacity of the pump will also be reduced when the pressure in the suction pipe drops. A certain reduction in pressure is always present in the suction pipe on account of the resistance of the flow in the pipe itself, and in the gas washers, but it should not be more than that which corresponds to a water column 2'-6" to 3'-3" in height. In order to measure the pressure and find the point of greatest resistance, it is advisable to connect water manometers to the pipe before and after entering the washer, as well as near the pumps. It is then possible to determine whether the excessive resistance is due to the irregular working of the

saturation tank into which the necessary amount of saturation gas is injected. From this tank the partially saturated juice flows into a second tank, through a riser leading from the bottom of the first tank to the top of the second, in which it is treated with enough gas to bring the alkalinity down to the required point. For the second tank, or better for a third tank, into which the second overflows, a prebeater may be substituted. By careful regulation of the flow of the juice and the gas, a very good and uniform saturation may be obtained.

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washers or to the choking of the suction pipe with ashes from the lime kiln.

An increase in the time of saturation also occurs when too much lime is added to the juice or when the milk of lime is made too thick or too much dry lime is added. Besides these obvious delays in saturation, there are others which are probably connected in some way with the composition of the diffusion juice, but for which no satisfactory explanation has as yet been found. Pectins probably play a part in the matter, as a poor saturation due to a poor diffusion juice only occurs when working unripe, heavily manured or unsound beets, and is connected with the way the diffusion is handled. Pectins, when present in any quantity, seems to thicken the juice, combining with lime in much the same way as sugar, but the thickening so caused is less easily done away with, and in consequence the saturation lasts longer. As a means of remedying this, it is advisable to change the work of diffusion in such a manner as to work quickly and use only moderately high temperatures. In cases of very retarded saturation, no matter what the cause, the quality, color and purity of the juices suffer. Therefore, causes of the difficulties should always be sought as quickly as possible, and proper remedies applied.

A further troublesome disturbance, during saturation, is caused by excessive foaming. This phenomena also depends largely upon the constituency of the beets and the mode of diffusion, and usually occurs in conjunction with a poor circulation, so that the causes of both bad conditions seem apparently, to be the same. If the foaming is so violent that a large foaming space does not suffice, the only resource is an increased addition of fat or oil.

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CHAPTER IX.

THE FILTER PRESS STATION.

From the saturation tanks, the defecated juice is pumped, under pressure to the filter presses. Juice lifters or air pumps are rarely used, on account of the great number of evils connected with them, such as their uncleanliness and the dilution of the juice caused by condensation of steam, when the latter is used instead of air, and also the difficulty of regular pressure in the work. Plunger pumps are most generally in vogue, working either singly or doubly, and constructed to work either with automatic pressure regulations or under manual direction. In the suction line, a stone catcher should be placed, so that stones and grit can be caught before entering the pumps or the narrow orifices of the filter presses. The pressure of the pumps should depend on the size of the press and filtering surface, and also on the qualities of the cake. In general, a pressure of 2 to 3 atmospheres is none too high and the cake so obtained is then sweetened off. With bad cake or small filtering surfaces, the pressure should be increased to 4 - 8 atmospheres. A higher pressure is not warrantable since the frames in the presses are apt to be broken by uneven pressure on one side or the other. To properly guage the pressure, manometers or pressure gauges should be placed on each press. In the pressure line, behind the pumps, a reservoir should be installed so as to give a regular pressure on the juice when the pump work is irregular.

For filtration, either "chamber" or "frame" filter presses are used. The chamber presses are those in which the juice canal lies in the middle, and the cloths are filled through holes in the center for this purpose. These presses have the advantage that they hold solid better on the outside because the outer surfaces have 4 layers of cloth. The disadvantages are, that they take a great deal of time to

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THE WATER PRESS FILTER.

renew the cloths; the filling of the frames is not satisfactory, and the holes in the cloths are apt to tear and fray. The frame presses are most often used. In these, the cloths lie flat between the frames so that the dressing of a press is not difficult and can be carried on rapidly. The disadvantage of these presses is, that they break more readily with high pressures, but this can be prevented very largely by careful work and preventing the cloging of the cake in the holes on the frames, and at the same time, being careful that the cloths are flush and unwrinkled between the frames. A further disadvantage is that the cloths on the upper edges of the frames become easily injured and torn. This point is particularly noticeable when the workmen slam the frames together, or else use high pressure in closing their presses. It is immaterial whether gasket, filter cloths, or rubber rings are used to close the opening in the frames, provided good joints are obtained.

The size of the filter presses, as well as the size and number of the frames and plates, depends on the work. The joints of the press must be such that the work can proceed uninterruptedly. Hence, it is poor policy for a small factory to use a single large press, or to use one large one and one small, because with such methods, when the large press is fresh and empty, not as much juice can be worked as the press has capacity for; while the juice and the work are held back when the press is nearly full. At the same time, it is improper for large factories to use a number of small presses, because of the increased labor and cloths, essential.

The size of the frames varies between 600 and 1,000 m.m., square. The number in a press or in a section of a double press, varies from 20 to 40, and the thickness of a cake is from 15 to 30 mm. A very thick cake is a great disadvantage with bad scums. With good easily filterable material it is a decided advantage and in some factories the cake is made as thick as 30 mm.

The filtering surface essential for any definite amount of beets is absolutely undeterminable on account of extreme variation in the filtering qualities of the juice. However, the surface should be sufficiently large for the worst kind of work, in order to be absolutely certain of being able to work to full capacity at all times.

During campaigns, it is not necessary to clean the filter frames or the passages in the same. After each campaign, this work must be carefully attended to. The holes in the screens, the cake and sweetening off holes, as well as the outlet holes, must be all carefully freed from scale. When brushing and scraping is not satisfactory, the plates should be immersed in a diluted solution of Hydrochloric acid, or concentrated acid should be pumped through all of the passages. In all cases, they must then be carefully washed off with water, in order to remove the last traces of acid, and in order to further prevent any possibility of rusting, they must be carefully varnished. When too great a wearing of the plates is feared by dipping in acid, properly constructed scrapers can be used with advantage. In many factories, hot dilute Hydrochloric acid is pumped through the presses at the end of each campaign, but such methods of cleaning, though they save much labor, must be used with a great deal of caution, in order not to injure the pumps, pipes or cocks on the presses.

The choice of the cloths is of great importance for good work, but here also there are a great many varying conditions. In some factories, heavy material gives the best results, while others use cloths of very light weave. As a rule, jute material is used in the first saturation press because it is the cheapest and is least injured by the alkalinity of the juices. The durability of the cloths depends entirely on the alkalinity and temperature of the juices. When the cakes are

bad, the cloths must be changed and washed frequently, and care must be taken to choose cloths with a good weave and of good material. When the beet juice gives a good cake, cheaper and lighter cloths can be used just as satisfactorily, and these can remain on the presses until they become totally clogged, a period of fourteen days or longer. Of course it is necessary for the cloths to have an even woof and no holes or rents.

In many factories it is the custom to change only single cloths when they are found to give poor or clouded juices. This custom is not as satisfactory as changing the entire press, because portions of the press are apt to filter unevenly. When cloths show signs of wear, the entire press should be redressed in order to fill and sweeten off the press evenly.

Various kinds of washing machines are used to clean the cloths. Those which are most satisfactory are built with rolling cylinders, in which the cloths are kept agitated into hot water, which enters at one end and flows off at the other.

It is not necessary to soften up new cloths when using jute material. In order to give the cloths a good resting surface on the frames, a fine lead beading is placed on the margin. Nowadays, filter plates are made with long corrugations or canals to take the place of the sieves. These have the advantage of being more readily cleaned than the screens and there is no reason why they should be any harder on the filter cloths.

Properly formed cakes should lie evenly distributed between both cloths. The heavier portion of the cake, as particles of grit etc., fall as a rule, to the bottom portion of the frame as long as the contents are soft; and the lower portions probably fill faster than the upper, but on the whole, the cake forms fairly evenly over the

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entire cloth when the pumps act properly, and the stream of liquid is properly injected. One can always tell irregularities of work by the different colors of the layers of the cake, which show on fresh fractures. When the saturation is carried on singly, every tank shows a differently colored cake; hence, the layers are sometimes yellow and sometimes slightly blue in color. With continuous saturation, cakes are very evenly colored.

When the inlet valve of an empty press is opened, the juice is thrown, in a stream against the outlet valve; the cake is immediately deposited on the cloths, and as the layer becomes less and less permeable, the more the juice is held back, until after one or two hours the press is entirely filled and the juice comes out of the cocks in a very small stream. The foreman must know, from experience, when his press is sufficiently filled. Too long a filling is a waste of time, while an under filling of the presses with too little cake prevents the proper sweeping off and causes a smearing of the cloths and the frames, so that the presses leak and run poorly. The better and firmer the cake, the more readily one can sweeten off and maintain regular work; hence, even though the presses run slowly, they should be allowed to fill thoroughly. It is impossible to increase the capacity by emptying an underfilled press merely because it runs slowly, because the difficulties encountered with soft cake take far more time to remedy in the end than proper work in the beginning.

The cause of slow and bad running presses, and poorly filterable juices of mushy constituency, depends on either the qualities of the beets or the methods of work. The diffusion work has an unquestionable influence on the qualities of the cake. When the beets are the cause of poor work in the presses, a change in the work of the diffusion battery alone is often a great help.

An increase in the addition of lime within certain limits is seldom much of an advantage, aside from which fact, most factories have an excessive amount of cake for the capacities of their apparatus. Neither has the oft recommended boiling-up of the juice any decided advantage, for by this means, only the packing of the press is made more satisfactory, without obtaining a better cake than with temperatures of 80 to 90 degrees C.; neither does a change in the alkalinity of the saturated juice aid materially. In most cases, the only satisfactory method of improving the press work is a frequent change of cloths. Since the difficulties at the beginning of the campaign are, as a rule, due to unripe beets and unskilled labor, these troubles should vanish after a comparitively short period of work.

From the preceeding, it is very apparent that poorly saturated juice, such as that which is under, or that which is over-saturated, is bound to filter poorly. In order to obtain proper saturation, great care must be exercised, particularly when the cake has bad characteristics. Intermittently bad running of the press can often be attributed to incomplete saturation of single tanks, or to leaks in the discharge valves in the line. Sometimes the foaming over of one tank into another is also a source of trouble. Such causes of poor cake are easily detected by titration of the juices in the line on their way to the presses, showing a decidedly higher alkalinity than those which are properly saturated. Such titration control should be made frequently and regularly. A slight increase of the alkalinity sometimes occurs when small grains of lime or saccharate occur in the juices and dissolve slowly in a small layer of juice. As a rule, this increase of alkalinity does not exceed 0.01% of CaO. Soft mushy cakes occur most often from too slight pressure in the pumps, hence, a manometer in the pressure line is absolutely essential for the proper supervision of the work.

The sugar content of the unsweetened cake is the same as that of the defecated juices, though the amount of insoluble saccharate is extremely variable. As a rule, the cake consists of 40 parts of solid matter and 60 parts of juice. As the latter contains 10 to 12 parts of sugar, the sugar content of the cake is between 6 and 7%. The sweetening off of the cake should be so arranged that the sweet water should be as concentrated as possible, with a thoroughly good digestion of the cake. This result can only be obtained when the juice is forced out of the cake by suitable means with water. In some factories the cake is removed from the press unsweetened; is then mixed with water and resweetened in the presses. By this means however, a very dilute water is obtained, with the same amount of sugar loss in the cake as when sweetening off in the presses. The first method has the advantage, that the very simplest of filter presses can be used.

The sweetening off from the presses can be arranged in one of several ways. Either the water enters through canals at the side of the cake frame, permeates it and flows off at the other side, or the water takes the same course as that of the juice, entering in the middle of the cake, permeating both halves and flowing away on both sides. Details which cannot be omitted in the sweetening off of the presses are heterogeneous cakes of even thickness, throughout the press, and cloths of the same woof and permeability. If the cake is thinner and softer in one portion of the press than another, the water passes through that portion in excess, and the thin portions are sweetened off long before the thicker parts of the cake. This error is particularly noticeable when washing off with water at high pressure. An altogether even distribution of the cake is hardly possible, for on account of the construction of the presses, the cakes are bound to have uneven and bad spots. With the chamber presses the bad portions of the cake are apt

to lie on the periphery of the frame where the cakes are thinner and are apt to be mushy; with the frame presses, the difficulty is apt to lie between the iron frame and the cake where the adhesion of the scum is less than the cake underneath. It is not advisable to pack a cake too hard, because of the difficulty and waste of time in sweetening off and the excessive water pressure necessary, also on account of the extreme variations due to slight differences in the thickness of the cake.

In order to prevent the evils of an uneven or too great a pressure, the pumps are, in many factories, not allowed to work on the filter presses but are led to a reservoir in which the pressure is regulated to 1-1/2 atmospheres. The presses should sweeten off better and quicker by this method than with pumps acting directly. A high water pressure is rarely coincident with a good sweetening off of the cake. But with lower pressures the sweetening off takes an undue amount of time and the number of presses must be increased.

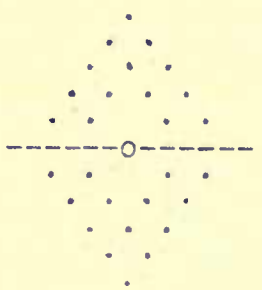
Frequently the pressure of the sweetening off pump is regulated by that of the first carbonation pump, so that the former is only a trifle higher than the latter. When the first carbonation pump is worked with a low pressure, the differences can be increased, though it is better to determine the pressure of the sweetening off pump, so that at any definite time a certain amount of dilution can be obtained. The pressure of the sweetening off pump must necessarily be regulated in accordance with the properties and thickness of the cake; but a certain maximum limit must not be passed, so that the cake will not be injured or sweetened off irregularly. The maximum pressure of sweetening off with little water, should not exceed 2 atmospheres. Every increase of pressure causes an increased dilution of the sweet water, with cakes of the same sugar content.

The duration of sweetening off with a sugar content of 1% is, with low cakes, from 20 to 30 minutes, but one obtains on this basis 100 to 150 parts of sweet water on every 100 parts of cake. If the pressure is increased, which must be the case with poor cakes, the amount of sweet water increases, though the time is also shortened. As a rule, it is impossible to obtain a lower sugar content of the cake than 1%. German factories are generally satisfied with an average sweetening off of 1-1/2 to 2%.

The question as to whether or not hot or cold water should be used in sweetening off is, as yet, undetermined. It is certainly not apparent that the temperature of the water has any influence on the purity of the sweet water, as long as pure clean water is used. Since considerable pure, hot water is obtained from the bodies of the evaporators, it may just as well be used to sweeten off without taking the trouble to cool it. The single advantage of cold water is, perhaps, that it cools off the cake and thus exposes the laborer to less annoyance with hot vapors when the presses are emptied. Cold, "hard" spring water should be used with caution when sweetening off, since in the hot chambers of the presses it is apt to deposit scale in contact with the lime-saturated juices, and thus clog up the cloths, channels and perforations of the screens. A deposition of scale can also occur by the use of evaporator waters, when these contain Ammonium Carbonate, though this is apt to occur only when the thin juice is super-saturated with carbon dioxide. It is evident that the sweet-water dissolves much organic matter out of the cakes, in consequence, the last sweet-water is of lower purity than the first, though this always remains sufficiently high so that a defecated sweet-water gives a very good crystallizing fillmass. Under no conditions is the cake to be sweetened off as far as possible, even though the number of presses would allow it, on account of the excessive dilution.

The choice of the method of sweetening off to be used, whether through the sweet-water channels and full cakes, or through the cake channels with half cakes, depends on concomitant circumstances. As a rule, it is best to sweeten off through the sweetening off channels, when the presses are properly constructed, for under such conditions, the cake is sweetened off with more certainty and evenness and the juices are less diluted. In factories where milk of lime is used for defecations, the more diluted sweet-waters should be separated from the rest of the liquor and used to dissolve the lime. Since 5 to 6 parts of water are necessary to dissolve one part of lime, and one part of lime gives from 4-1/2 to 5 parts of cake, it is apparent that one need not dread an excessive dilution of the sweet-water, for 150% of the weight of the cake is necessary to dissolve fresh lime. In contrast to this, in factories with dry defecation, every unnecessary dilution must be avoided in order to prevent an extravagant use of fuel.

The cake (Pressschlamm or Scheideschlamm) falls from the presses into wagons, or into conveyors, or mixers underneath the presses in which it is mixed with water to form a thick mush so that it can be conveyed to the sewers or pumped to settling ponds. As a fertilizer of the soil, those cakes which have the least lime and the greatest amount of phosphoric acid and nitrogen are the most valuable.



CHAPTER X.

THE SECOND CARBONATION AND FILTRATION.

After coming from the first presses and running in the troughs, the juice is cooled off to such an extent that it has to be reheated, and should be brought and maintained at a temperature of about 100° C. This high temperature is essential for the action of the lime on the remaining organic matter, and to prevent the formation of any double salts of lime and carbon-dioxide. In the second carbonation the heating must be done before the addition of the lime to the juice, in order to prevent heavily limed juice being brought to the evaporators, for juices saturated with lime at 70 to 80° C., precipitate insoluble saccharate on heating to 100°C. As a rule, 25% of lime, in the form of milk of lime, is added to the juice just before the second carbonation, though this second addition is not usually necessary, because it contains sufficient lime in the first carbonation to thoroughly decompose the organic matter at the high temperature of the second. When dry defecation is used in the first carbonation, the second addition of lime should be entirely omitted. The addition of dry lime into the hot juice is apt to form considerable insoluble saccharate.

The second carbonation is generally worked continuously, the juices flowing from one tank to another after coming from the heater. Only two tanks are used, the juice being carbonated in the first and pumped from the second. A third carbonation works in precisely the same manner. The essential consideration for both the second and third carbonation, is a high temperature. When only a second saturation is used, carbon-dioxide alone, or carbon-dioxide andsulphur-dioxide are used together. With two after-carbonations, the first is operated with carbon-dioxide alone, and the second as stated above. The question as to the advisability of two after-carbonations is quite unsettled. It is difficult to decide whether a second and third carbonation afford an

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opportunity for more careful regulation of the operation, and less danger of injury by carrying the operation too far. Two saturations make the work more complicated and require more care, so that many factories operate just as successfully with one after-carbonation. A third carbonation is essential when there is any amount of magnesia in the lime or juice. Magnesia goes into solution when the juices are saturated below an alkalinity of .05, probably as Ammonium-magnesium-carbonate, or as Bi-carbonate of magnesium. Both salts are decomposed on boiling to magnesium-carbonate. In the presence of these salts, the alkalinity in the carbonation must be maintained at .05, and the correct alkalinity should not be reached before the juice is filtered. There is much diversion of opinion in regards to the amount of alkalinity which should be left in the thin juice. A general answer would be to have an alkalinity sufficient to give a neutral thick juice, at the same time thoroughly removing all the organic matters. When the thin juices are brought to neutrality with sulphuric acid, they have a brighter color than alkaline juices, though the color cannot be relied upon for the work.

In reheating, the juices are usually maintained above a temperature of 100°C., for some time, often in the preheaters the temperature reaches 115 or 120°C., and is even above 100° C., in the first body of the evaporators. Only neutral or very weakly alkaline juices cannot be handled in this manner, since the alkalinity increases on boiling. Neutral juices usually decompose, giving dark colored juices, while with just sufficient alkalinity they are not noticeably injured when the temperature does not exceed 115 to 120° C. Intense heating really seems to improve a juice for the alkali acts energetically and destroys the nonsugars such as Amides and Albuminoids, which remain unacted upon in the defecation. The alkalinity in such cases shows a

opportunity for more careful regulation of the operation, and less danger of injury by carrying the operation too far. Two saturations make the work more complicated and require more care, so that many factories operate just as successfully with one after-carbonation. A third carbonation is essential when there is any amount of magnesia in the lime or juice. Magnesia goes into solution when the juices are saturated below an alkalinity of .05, probably as Ammonium-magnesium-carbonate, or as Bi-carbonate of magnesium. Both salts are decomposed on boiling to magnesium-carbonate. In the presence of these salts, the alkalinity in the carbonation must be maintained at .05, and the correct alkalinity should not be reached before the juice is filtered. There is much diversion of opinion in regards to the amount of alkalinity which should be left in the thin juice. A general answer would be to have an alkalinity sufficient to give a neutral thick juice, at the same time thoroughly removing all the organic matters. When the thin juices are brought to neutrality with sulphuric acid, they have a brighter color than alkaline juices, though the color cannot be relied upon for the work.

In reheating, the juices are usually maintained above a temperature of 100°c., for some time, often in the preheaters the temperature reaches 115 or 120°c., and is ever above 106° c. In the first body of the evaporators only neutral or very weakly alkaline juices cannot be handled in this manner, since the alkalinity increases on boiling. Neutral juices usually decompose, giving dark colored juices, while with just sufficient alkalinity they are not noticeably injured when the temperature does not exceed 115 to 120° c. Intense heating really seems to improve a juice for the alkali acts energetically and destroys the nonsugars such as acids and Glutamides, which remain unacted upon in the defecation. The alkalinity in such cases shows a

decided increase which however, does not reach the point of neutrality, and there is no sugar destroyed, on the contrary, acids result from the combination of the alkalies and nonsugars, which unite with the freed ammonia.

The question as to whether or not the thick juice should be strongly or weakly saturated, depends on the last amount of lime added and whether or not it is precipitated as carbonic or sulphuric lime in either the thin or thick juice. The solubility of these substances in sugar solution, is also important here, since an extreme saturation of the thin juice can only be advantageous when the lime salts are as difficultly soluble in thin juices as in thick. Nearly all lime salts are, however, more difficultly soluble in concentrated sugar solutions than dilute, and in heating the thin juices, carbonates, sulphates and other salts of lime separate out on the tubes of the evaporators, whether the thin juice is alkaline or neutral. All conditions demand a permanently alkaline thin juice sufficiently alkaline so that the unsaturated thick juice (or "middle juice") will still remain alkaline. It is not proper to maintain any definite alkalinity of the thin juice; this should vary with the qualities of the juice and its contents after heating. In consequence, only the extreme limits can be given, below and above which it should not vary. The upper limit is that at which the alkalinity is such that the lime does not react or form saccharate, while the lower limit is that which will yield a soundly alkaline thick juice; for the latter an alkalinity of .05 to .10% or thereabouts is sufficient. The alkalinity of the thin juice must be increased when that of the thick juice falls below the point of neutrality. As a rule, an alkalinity of the thin juice of .03 - .05% (indicator Phenolphtalein) is very small, very little of the lime existing as CaO, most of it being combined with acids. The greater part of the permanent alkalinity

depends on organic bases and ammonia. If the juice acts energetically on the alkalies or the free lime, during evaporation, as is often the case with unripe beets, the alkalinity of the thin juice should be maintained as high as possible. At the same time, it must be noted that strongly alkaline juices create a great deal of scale in the evaporators, which retards evaporation.

The final alkalinity should be the same whether the second saturation is carried on with carbonic or sulphurous acid, and depends on the purity and ease of working of the juice. For simplicity and cheapness of working, carbonic acid is the most advantageous and affords the opportunity of omitting the treatment of the thick juice with sulphurous acid. When two second saturations are considered desirable, the alkalinity of the first should be maintained at from .01 to .02% higher than that of the thin juice, in order to effect a third saturation. A double filtration of the thin juice is absolutely essential whether one or two second saturations are used, in order to obtain an entirely clear juice for evaporation. For the first filtration, filter presses are used, which are covered with thickly woven cloths, cotton or jute. For this purpose, filter presses are used without sweetening off channels, for such channels have the disadvantage of affording no means of shutting off the juice from the main body of the liquid, when any special cock begins to run dirty. The simplest presses are sweetened off through the lime hoppers, though, in general, the last cakes are not sweetened off at all, for the amount of cake scarcely amounts to .1% of the weight of the beets and the loss of sugar in this manner, at the most, can hardly be noted. If a large quantity of cake is formed, it is best to return it to the first saturation to be resweetened in the first presses, in order to decompose the insoluble saccharate which often forms in the second saturation, the unsweetened cake of which sometimes runs as high as 4 to 7% of sugar. The filtration of

the cake of the second saturation seldom offers any difficulties. At times though, the presses stop running in a short while and there is not a full cake in the frames, while the cloths are covered with a smeary scum. This condition occurs generally when the first saturation yields a poor cake or when the first is carried too far. Under such conditions as previously described, carbonate of magnesia goes into solution and separates out again in the second saturation. Nearly all precipitated salts of magnesia, as well as the carbonate, are slimy and filter with difficulty. The second filtration of the thin juice is best accomplished in bag filters of Daneks, which afford a large filtering surface in a small space with little pressure. Little pressure is essential in order to prevent the smallest particle of cake from being forced through the woof of the cloth. The advantages of any one type of apparatus depends on the ease with which the cloths can be changed and their durability. A very good and reliable filtration is that over gravel, coarse sand or similar granular material. On the whole, these filters need more manual work in renewing filter material and must be frequently washed in order to work satisfactorily. Much praise has been given to filtration through particles of swimming cork which floats on the upper surface of the filter, the juice circulating from the bottom upwards. Filtration through sawdust and excelsior is also often successful. Frequently, material is added to the thin juice which allows fine particles of a cake to coagulate, thus affording a more satisfactory separation. For this purpose, fine sawdust, cellulose, and boneblack are used; the sawdust is prepared by soaking in a weak alkaline solution until the addition of fresh liquor is not discolored; with boneblack, care must be taken that the correct kind is used in order to obtain a clear colorless liquid, such that the acids contained therein do not unite with the alkali of the juice to cause a decrease of the latter. Every thin juice filter should be provided with two troughs from which the clear juice can be led from one to the evaporators and returned from the other to the second carbonation.

CHAPTER XI.

OTHER METHODS OF JUICE PURIFICATION.

Besides the purification by means of lime and carbonic and sulphurous acids, there are more than 300 other methods for decolorizing and purifying the juices. Forty utilize acids of sulphur, 25 those of phosphoric acid and its combinations, 23 various organic acids and their combinations, 47 alkalies, alkaline earths and their salts. 69 metals and metallic salts, 56 organic materials, and 12 depend upon electrolytic methods. (November 1903).

Some of these materials are used in the diffusion battery, some in the raw juice, the thin juice, the thick juice or the syrups. Most of the methods of purification are applicable only in special cases, while the majority of the materials used are too expensive to warrant any practical application. In some cases poisonous materials are introduced into the juice, which, even if they do not affect the sugar, always appear in the molasses, injuring the sale of the latter as cattle food. As far as purification of the diffusion juice before defecation is concerned, the action must be mostly on the organic materials which occur in largest quantities in this condition; the same applies to the molasses. As a rule, either the methods yield comparitively poor results or they are too costly. Only few substances are really advantageous for addition to the thin or thick juices. The most important of these are the carbonic and sulphuric alkalies, or quick lime, which, more than anything else, converts the organic lime salts into corresponding alkaline salts. Phosphoric acid is also used which precipitates lime as phosphates. Baryte is used to precipitate sulphuric acid and combinations of organic acids; the chloride of barium should increase the crystallization. Magnesia, which sometime ago was said to have very satisfactory action, stands far behind lime in reference to its ability

CHAPTER XI.

OTHER METHODS OF JUICE PURIFICATION.

to purify the juices and render them filterable. Clay acts as a clarifying agent on the raw juice, Tannic acid precipitates albumen, while carbon as coke, boneblack, or charcoal, acts as clarifiers without purifying the juices. Other bleaching substances are sulphurous acid, hydrosulphurous acid, and ozone, with or without the conjunction of boneblack. Some of the salts of the heavy metals, such as zinc, tin, and lead, also decolorize. A good action on the raw juice is obtained with electrolysis by soluble lead or zinc electrodes, using at the same time a method of Dialysis, but the method is too expensive to be practical, and the sugar losses are too great.

In the diffusion, acids such as oxalic, phosphoric, or hydrochloric, used to be used in small quantities to decrease the solubility of substances, which in the filtration of the saturated juice caused a poorly filtering cake; the consequences of their use were undoubtedly unimportant, excepting the injury to the walls of the diffusion cells. The addition of antiseptics such as phenol or formaldehyde, in order to prevent the development of gas or fermentation, are almost entirely useless, for the substances are too costly to add in large quantities or else give a bad taste and odor to the sugar.

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CHAPTER XII.

E V A P O R A T I O N.

In evaporation, the thin juice should be concentrated from 12 to 13 Brix to approximately 60 Brix, and about 80% of water should be evaporated in the operation. When the heating surfaces of the evaporators are too small or lacking in capacity, concentration to 50 Brix is all that can be obtained; but this naturally necessitates the use of an increased amount of fuel. A properly constructed evaporating station should be so arranged that even under the poorest circumstances, one would never obtain a thick juice less than 65 to 60 Brix. a density of 65 to 70 is not advisable on account of the difficulties in boiling, and the possibility of crystallization of the mass by cooling of the liquors in the pipes.

The amount of thin juice usually obtained per 100 kg of beets, using the dry defecation process and 2% of lime, is as follows:----

Draw in the diffusion, about 105 litres	=	110 kg.of beets.
Sweet-water from the presses (125% of 8% cake)	=	10 " " "
Various waters of condensation	=	2 " " "
Total thin juice		122 " " "

In factories which use the wet defecation or milk of lime process, considerably more lime is used and there is in consequence, more sweet-water. As a rule, the sweet-water is not used to dissolve the lime, and the thin juice obtained is about 125 kg per 100 kg of beets.

Diffusion juice with a sugar content of 12 to 13% gives therefore, a thin juice of 10-1/2 to 11-1/2 percent of sugar. In factories with a daily capacity of 500,000 kg of beets, 625,000 kg of thin juice are made, or a total of 1-1/4 to 2-1/2 million kg to be concentrated for every 10,000 to 20,000 kg. worked.

EVAPORATION.

In evaporation, the thin juice should be concentrated from 12 Brix to approximately 60 Brix, and about 80% of water should be evaporated in the operation. When the heating surfaces of the evaporators are too small or lacking in capacity, concentration to 50 Brix is all that can be obtained; but this naturally necessitates the use of an increased amount of fuel. A properly constructed evaporating station should be so arranged that, even under the poorest circumstances, one would never obtain a thick juice less than 55 to 60 Brix. A density of 65 to 70 is not advisable on account of the difficulties in boiling, and the possibility of crystallization of the sugar by cooling of the liquors in the pipes.

The amount of thin juice usually obtained per 100 Kg of beets, using the dry defecation process and 2% of lime, is as follows:----

Juice in the diffusion, about 105 litres = 110 Kg. of beets.

Sweet-water from the presses (12% of 85 cake) = 10 " " "

Various waters of condensation = 8 " " "

Total thin juice 123 " " "

In factories which use the wet defecation or milk of lime process, considerably more lime is used and there is in consequence more sweet-water. As a rule, the sweet-water is not used to dissolve the lime, and the thin juice obtained is about 135 Kg per 100 Kg of beets.

Diffusion juice with a sugar content of 12 to 13% gives therefore, a thin juice of 10-1/2 to 11-1/2 per cent of sugar. In factories with a daily capacity of 500,000 Kg. of beets, 525,000 Kg of thin juice are made, or a total of 1-1/4 to 2-1/2 millions Kg. to be concentrated for every 10,000 to 20,000 Kg. worked.

For the evaporation of such immense quantities of water, there have been systematic improvements in evaporation installations. The heating surfaces are, as a rule, tubes expanded into end sheets, the juice circulating around the outside of the tubes. The length of the tubes was, in the earlier apparatus, 1.25 to 1.50 m; with later types, 3 to 4 m., and they range from 20 to 50 mm. in diameter. The important features of construction have not been altered much in the improvement of the apparatus. Every evaporator should be provided with indivual thermometers and quick-silver vacuum gauges, as well as the proper peep and light glasses, so that the contents can be carefully watched.

In the single effect evaporator, 1 kg of steam evaporates at best 1 kg of water. A better utilization of the heat in the steam can not be obtained unless the steam developed is again used for evaporation or heating. Hence, we would hardly be justified in considering the economy of steam when studying evaporating apparatus, but should confine our attention to the conditions under which these apparatus give off the greatest amount of water from the heating surfaces. We must also place our attention on the greatest possible capacity and various coincident evils.

The best construction to attain this object will be when the following conditions of heat transference are thoroughly fulfilled. The transference of heat from the heating surfaces to the boiling fluid, increases as:-----

1. The velocity of the circulation of the juice on the heating surfaces.

2. The juice level and the juice pressure on the heating surfaces decreases.

3. The speed with which the heating vapor is condensed on the heating surfaces.

4. The speed with which the condensed water is removed from the heating surfaces.

5. The completeness of the vacuum in the heating space.

6. The cleanness of the heating surfaces from scale and deposits, so that the heat will be conducted better through the heating surfaces.

7. The less viscous the juice is the better the work.

8. The hotter the juice becomes.

9. The increase in temperature between the heating vapor and boiling juice.

These conditions must be obtained by the simplest methods, so that the practical operators of the evaporators will have a simple and easily manageable apparatus. Then too, care must be taken to avoid any losses of juice, and lastly, the installation must not be too expensive. All such machinery, to be used in sugar factories, must be of the simple construction, for the evaporating apparatus has to work day and night, and there are very few hours Sundays during which they can be cleaned and repaired, so that all installations which are apt to give the slightest trouble should be discarded.

As a rule, the vertical and horizontal types of apparatus, in use in most factories, are satisfactory as far as simplicity. With many types of construction, particularly with the theoretical type of spray apparatus, losses and irregularities of work have occured, so that they have met with little favor in modern practice. In places where the tube systems are used, either vertical or oblique tubes are used for the evaporation and boiling. For certain purposes, these have advantages, though, it is hard to understand why they should be used more than the properly constructed types. One must bear in mind, that the capacity of an evaporator depends, in the end, on a choice between the use of two types of construction, in which one must pay as much

attention to the capacity per sq. ft. per heating surface, as when using double the area in another construction in which the capacity is only half as great. Then too, the capacity of an evaporator has, as a rule, nothing in common with the heat-economy of the entire system, for this depends on the proper combination of the separate bodies.

The capacity of the single effect evaporator, is a most important consideration from first to last. With successful types of apparatus, one must be able to constantly work it to its full capacity. By proper thought in this direction, one can, with very simple means, reach excellent results and obviate costly increases of the evaporator station. Hence, it seems essential to consider the means of increasing the capacity of existing types of apparatus.

The most important influences on the capacity of the evaporators, are the height of the juice and the juice stream. Earlier, it was thought that one should never allow the juice to fall below the level of the tops of the tubes, and that the juice should never be maintained at a height less than the length of the heating tubes, that is, from 1-1/4 to 1-1/2 m.; but the pressure, and consequently the boiling point at any spot on a tube increases with the height of the column of juice around the heating surface. Against this consideration, we have the experimental data which shows that thermometers placed both at the top and bottom of the tubes give exactly the same temperatures. This is on account of the circulation of the juice, which is sufficiently active so that there is no superheating at any one point on the heating surfaces, and the excess heat in the form of steam is rapidly mixed with the juice current so that the temperature of the juice, as far as it can be measured with thermometers, is the same throughout the mass. It is nevertheless apparent, that at any particular moment, there is a difference in temperature between the

steam being developed at the top and the bottom of a tube. The temperature difference between the heating vapor and the heating surface, decreases also when the juice pressure increases, and since the evaporation is proportionate to the difference in temperature, the capacity is correspondingly diminished as the juice pressure increases. Hence, in vertical apparatus, the heating tubes have been considerably shortened; but this feature necessitates apparatus of large cross section, in order to obtain the same heating surfaces. But on other considerations, the diameter should not exceed 3 m. A shortening of the heating tubes is not only unnecessary, but is also a detriment to the capacity when working with low juice levels in the evaporator. The reason for this is, that the bubbles of vapor coming off of the liquid, entrain considerable sugar and cause excessive foaming, which is not only a drawback to the work but is also a positive loss. The longer the tubes are, within definite limits, the faster the circulation will be in them, providing that the pressure in the bottom portion is not too great.

The depth of the juice, which can always be measured, by communicating gauge glasses, depends on a number of conditions such as the viscosity of the juice and the volume of vapor given off. In consequence, the thick juice bodies can be maintained at a lower level than those filled with thin juice; the proper level must be determined by experimenting. It is only essential to maintain the juice at a sufficient height to cover the tops of the tubes. With horizontal apparatus, the juice level should also be maintained as low as possible, though as good a circulation can never be obtained as in the vertical types. On the other hand, with this type of apparatus, it is possible to install a very large heating surface with a small amount of head-room, particularly when the apparatus is coffer shape, which is really perferable to all other forms.

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In order to increase the circulation of the juice in the vertical types of apparatus, circulating wells are placed in the center so as to make a positive circulation in one direction. Sometimes the circulation is aided by means of annular spaces between the tubes.

Sometimes staves of wood or enameled iron are hung in the heating tubes; these, in section, are in the form of a cross, with a slight spiral twist. The wooden staves have the disadvantage of becoming soft and decomposing by the action of heat and alkaline juices, and after boiling out the evaporators with acid, they have a tendency to color the juice dark, and iron staves are too expensive for the work. The speed of the juice in the tubes can also be increased by using tubes of smaller cross section, so that the contents of the tube is less in proportion to the heating surface. Hence, smaller tubes are oftener used for the first than for the last bodies, in order to maintain the diameter of the tubes in a more satisfactory ratio to the volume of the evolved vapors. An installation which improves the circulation in the first body, is that of a so called "circulator" which consists of another smaller evaporating apparatus which is connected both above and below with the thin juice body; the circulator is heated with live steam. The vapor developed carries the juice up with it and serves as motive power through the tube system of the larger apparatus. The action of this circulator is, however, very doubtful. When the circulator increases the evaporation, the cause very probably lies in the fact that it is being run with high pressure steam, the use of which is very expensive.

The transference of heat depends further on the speed with which the heating vapor passes over the heating surface and upon the ease with which the condensed water flows off of the same. With vertical apparatus, the velocity of the heating vapor in the steam space is not very great, but the condensed water flows off of the tubes

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the vertical apparatus, the juice enters the bottom and upon the

space is not very exact, but the vapors which flow off of the tubes

very rapidly. With horizontal apparatus, the heating vapor attains considerable velocity, particularly when the heating tubes are of a small diameter, such as 20 mm. or under. This velocity is greatest at the point where the steam enters and decreases near the water outlet, until it becomes entirely nil. The condensed water flows away very slowly from the horizontal tubes, the lower portion of which are never free from water, even when the water is not spattered all over the tubes by the velocity of the steam. Improvements on vertical apparatus should be made in attemps to increase the velocity of the heating vapor, while with horizontal apparatus, the improvements should be in the line of proper drainage of the water.

All steam, live as well as exhaust, contains a small quantity of non-condensable gases such as air and small quantities of carbon dioxide and ammonia. In speaking of non-condensable gases, one usually means ammonia, though the greatest amount of ammonia from the condensed waters are absorbed. If the non-condensable gases are not withdrawn from the heating space, they gather and seriously retard the transference of heat. Hence, it is important to continually and completely relieve the evaporators of these gases. The importance of this is further obvious when one considers the dangers of strong corrosion of brass and copper, due to the action of ammonia combined with the oxygen of the air. Attempts have been made to use absorption apparatus to take up the ammonia in the exhaust steam lines, by using sulphurous or sulphuric acid, caustic potash etc.; the idea being that the ammonia salts obtained would cover the costs of the process. None of these installations have been successful, for they have yielded absolutely no profit, the quantity of ammonia in the vapor having been over-estimated. In the evaporation of thin juice, from 100 kg. of beets, only about

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10 to 20 grams of ammonia are developed, so that with normal work, only from 100 to 200 kg. of NH_3 can be obtained per day, even when there is a total absorption. This small amount does not pay for the costly method of the process which must be installed in every body of the evaporators; and moreover, at best, only prevents corrosion, for gases other than ammonia remain in the steam and are drawn up with it. Gases such as carbon dioxide, which are developed in large quantities, are frequently due to the over-saturation of the thin juice. An entire separation of the gas from the steam occurs normally, in the heating space in which, though there is rapid circulation, there are places where the motion is slight and where the gases collect. Experience has shown that with vertical types of apparatus, the brass tubes are attacked only in their upper portions, because it is there that the gases collect. Hence, the relief valves should be put in the upper tube sheets, and should be located farthest from the steam inlet. This is particularly essential when there are no steam baffles to remove the condensed water and traces of steam-vapor. When there are several superimposed steam baffles, it is best to put the gas relief line in the middle, between the plates. If the corrosion of the heating tubes still continues in other portions of the evaporators, relief valves should be placed in close proximity to these spots, in order to prevent the deteriorating influences of the gases. Care must also be taken that the baffle plates themselves do not bind the gases.

With horizontal apparatus, the steam inlet is always on one side, and the non-condensable gases are carried with the condensed water to the end of the tube. Hence, the baffles are placed only on the upper portion of the exit chamber. If the tubes are not entirely horizontal but bent, gases are apt to bind in the tubes and cause complete decomposition in a short time.

As previously mentioned, it is impossible to entirely absorb the gases without taking up correspondingly large amounts of steam, the amount of which can only be determined by experimenting. A small loss of steam is less dangerous than an excess of gas, which causes corrosion of the tubes and a decreased capacity of the apparatus. Great care must be taken to properly regulate the amount of gas to be taken from the steam space to the thin juice body, for it is there that the greatest amount of gases are developed, while in the thick juice body where the heating vapor has comparitively a low tension, the gases from the steam should be removed from large openings. The escape valves on the thin juice body need only have a diameter from 5 to 10 mm., while on the last bodies, they should be from 25 to 50 mm., and never less than half open. In order to maintain the heat losses within normal limits, the drawn off vapors, which contain hardly 1% on non-condensable gases, are not led directly to the condensors, but out of the heating space into the juice space of the same body, so that the steam can be fully utilized in the following bodies.

For a sufficient and quick vacuum, great care must be taken in installing the apparatus, or the heating spaces are apt to become bound with air. In order to utilize the heat of the steam, there must be close contact with the heating walls. The materials used for the tubes are brass, iron or steel; copper is rarely used for heating, except for the coils of the vacuum pan. The conductivity of the metals varies, but this property does not play any important part as long as the surfaces are kept free from scales and deposit. A point of greater importance is the thickness of the walls, though with poorly conductive iron, the walls are, as a rule, thicker than with brass. A very important consideration is the quality of the outside surface of the metal, not only that in contact with the juice, but also that next to the steam.

Brass tubes are preferable to iron because, in a comparatively short time, the latter are certain to be covered with a layer of rust. This cannot be removed and conducts heat very poorly. Many factories discard iron tubes, even when very thin, because of the ease with which they are attacked when boiling out with hydrochloric acid, and after short usage have to be renewed.

On the juice side, the deposition of scale is the main consideration. There are very few thin juices which deposit absolutely no scale, even though they filter and boil satisfactorily. If the thickness of the scale remains within reasonable limits, the capacity of the apparatus is not apt to be greatly impaired; in course of time, however, the scale becomes so thick that it is absolutely essential to remove it. The deposition of scale varies greatly in the different bodies, the largest amount coming down in the last effect, on account of the quantity of the difficultly soluble lime salts present. If the second saturation is poorly managed and if not carried on sufficiently hot, or if the filtration is not careful enough, a thick incrustation is very apt to show in the first body. This scale carries, in conjunction with it, particles of lime cake which deposits in the first body, and the deposition in the last bodies is also increased on account of the extra amount of lime. Under such conditions as these, the boiling of the thin juice before evaporation is not apt to decrease the deposition of the scale in the last body. As advantageous as it is to boil the juice before and after the first saturation, there is little gained by a separate station for that purpose, though such stations are useful in many countries, particularly when the work proceeds uninterruptedly, days in and out. In the majority of cases, filtration of the juice between the separate bodies is perhaps the most useful, and when the pressure is not sufficient, pumps should be utilized to force the juice through the filters.

During campaigns, the removal of scale by mechanical means, such as brushing or scraping, is only possible with vertical apparatus. With the horizontal types, the tubes have to be removed; but even in the vertical apparatus, mechanical cleaning is unsatisfactory and extremely difficult labor, hence, the chemical method of cleaning with soda and hydrochloric acid, or acid alone, is usually adopted. Such methods are quite satisfactory when one is able to clean the apparatus every week.

When the scale consists mostly of carbonate of lime, boiling it with dilute acid alone is sufficient. Very often, though, many other salts of lime are contained which are not at all, or only slightly, soluble in the dilute hydrochloric acid,- such as salts of sulphuric, sulphurous and oxalic acid, which with the scums of the juices form very stable salts in the apparatus. Other constituents of the scales are silicic acid, and aluminum and ferric oxides, which are derived from the lime and decomposed fats which are injurious insofar as they prevent the action of hydrochloric acid on the deposits. In the presence of such salts, it is advisable to boil out with a dilute soda solution in order to convert these lime salts into carbonate of lime and to further decompose the insoluble fatty matters. After thus altering the scale, hydrochloric acid attacks it quite readily. It is very seldom that this method does not prove thoroughly satisfactory, and under such circumstances, the reason is probably due to the excessive presence of silica and aluminum, and then mechanical cleaning only is satisfactory.

The hydrochloric acid used for boiling out must not be too concentrated so as to avoid dissolving any appreciable amount of iron from the walls of the evaporator; moreover, scales dissolve quite readily

in dilute acids. The amount of HCl should never exceed one per cent, even in the last bodies where the greatest amount of scale deposits, and in the first bodies it need not exceed one-quarter to one half per cent. In order to prevent the strong acid from injuring the inlet or any one portion of the apparatus, it should be distributed over the entire surface fully, by means of a pipe inserted in the middle and so arranged that a thorough mixture of the acid occurs with the water as soon as the boiling is commenced. The boiling out with acid should not be carried on at too high a temperature, nor longer than one hour. Working in this way the apparatus is rapidly brought to its original capacity, is never injured and will probably last twenty years. The vapors from the evaporator during the boiling out with acid should never be used with tail pipe water for injection into the boilers, for they are sure to have a decided acid reaction.

For boiling out with soda, a solution of one half to one and a half percent of Sodium Carbonate should be used. The boiling out with this solution should last as long as possible and should be at as high a temperature as can be reached, and in consequence, should be carried on as near atmospheric pressure as possible. Strong boiling in this manner makes the boiling out with acid more easy. After the boiling out with acid the apparatus should be immediately emptied of the acid-water and thoroughly sweetened off with clean, fresh water; it is deemed best to fill the evaporator with water up to the level of the vapor pipes. The water valves of all the bodies should be of such a type and arrangement that they can be safely shut off so as to prevent any misuse or leakage which would cause dilution of the juices.

In order to prevent any detonations in the apparatus from the

presence of fulminic acid gas, it is best to draw considerable air through the apparatus before starting to boil the juice. If the capacity is not up to its original point after boiling out, it is evident that the cleaning solutions have been too dilute, or that the boiling has not been carried on sufficiently long a time. The following week the work should be done properly. It is, however, not essential for the heating tubes to be entirely free from scale after boiling out, but the layer should be very much thinner and decidedly porous. It is obvious that the chemical solutions should be introduced rapidly so that as much as possible of the available time during cleanups may be utilized. One of the most important influences in the transference of heat is the viscosity of the juice. Since the juice to be evaporated should have a purity of 90 or more, it has a comparatively small amount of organic matter relative to the amount of sugar present. Hence, the organic matter is not apt to have much influence on the viscosity of the juice. Juices of equal concentration have practically the same viscosity, but this increases very rapidly as the condition of concentration of the juices increases and depends on the sugar content. Therefore, thick juices are far more viscous than thin juices, and the capacity of the thick juice bodies is less than that of the thin. In addition to this, the thick juice bodies work under more unfavorable conditions. The boiling point is less, due to the greater vacuum. The coefficient of transference of heat is less at lower temperatures than at higher, and at temperatures under 100° C., falls in far greater proportion than the temperature, while at 100° C., and over, the difference is not so great; hence, it is apparent that it would be best if all the bodies of the evaporators could be made to boil at about 100° C. But the highest allowable pressure of the exhaust steam is from 10 to 15 lbs., with a temperature of from 115 to 120° C., so that the total

available drop in temperature in the quadruple effect is too small. However, thick juice should be boiled at as low a temperature as possible in order to prevent decomposition. To avoid the bad effects of the inevitably high boiling point of the thick-juice-bodies, it is advisable to attempt to increase the difference in temperature between the lowest vacuum bodies. Not only the amount of heat is increased by this drop, but the coefficient of transference also increases. This coefficient is the amount of heat transferred from one square meter heating surface per hour per one degree difference in temperature.

In a properly constructed evaporating apparatus, there must be no mechanical losses of sugar. Among the causes of such losses are leaks in the tubes or tube sheets, though during actual work this can be the cause of little loss of juice because the pressure of the heating vapor is higher than the pressure in the boiling space in which the juice circulates. Of course, condensed water can get into the juice through the leaks, but the reverse is hardly ever apt to occur, unless the apparatus is shut down. Hence, it is very important to have good tubes and to have them properly expanded into the tube sheets. Before the campaign, the steam space should be completely filled with water under 14 pounds pressure, or more, and tested for leaks. In the horizontal apparatus, water should be put in the juice space when testing.

The second cause of sugar losses is entrainment of particles of juice with the vapor which is given off. Under these conditions, great losses can occur, since they happen under the most unfavorable conditions and can continue without any ready means of detection. Entrainment of the juice is apt to increase in accordance with the amount of steam and vapor developed in the juice; the more energetically the bubbles of vapor hit the surface; the greater the viscosity of the juice and the greater the velocity with which the juice is withdrawn.

In the first body of the evaporators, the danger of entrainment is very small because of the small vacuum, the comparatively small space occupied by the vapor given off and the low viscosity and slow speed of the vapor. But in the thick juice bodies, where the vapor occupies a space six times as great as in the first body, the impelled particles of vapor spray, to a greater or lesser extent, the viscous juice. When the particles are carried into the vapor lines, a speed of the vapor of 100 meters or more per second is sufficient to carry the solid matter over into the condensors from which it is carried away in the tail pipe waters. To catch these particles of juice, numerous forms of juice catchers have been installed in the vapor lines; the operation of each being based on the principle of catching the projected particles on sieves or hanging walls, from which the drip can be recovered. The efficiency of these juice catchers is rather doubtful. The best entrainment catchers are merely high walls in the evaporators on which the juice spray is caught and retained. The velocity with which particles are thrown upward is increased by the speed of the current of vapor and is only decreased by the action of gravity. In the vapor space, the gases attain a velocity of about 4 to 5 meters per second - the speed of a rather strong wind. Hence, it is apparent that it takes very little of the thin vapor to accelerate the positive upward movement. Against this action, gravity acts with equal force on both large and small particles. To make the vapor space high enough to catch the smaller particles in their upward motion, a space of three to five meters, above the surface of the liquid, would be essential, and at the same time there would still be danger of juice being lost in the thick juice bodies. It is generally thought that the juice is not lost in the form of solid spray, but as small bubbles which have very thin skins, light specific gravity, very small volume; and are readily

carried over with the stream. This bubble hypothesis does not satisfy any rational tests. It is quite evident that thick juice bodies with sufficiently high vapor space, lose little or no juice in the tail pipe waters. An excellent and easy method of determining whether or not the juice is carried over in the vapor lines is to put a collecting apparatus in the horizontal portion of the vapor line. A small portion of the particles carried over are caught on the projecting surface and are readily collected in the sampling apparatus: When the water obtained by this means contains only traces of sugar, or none at all, it is quite evident that the juice losses are slight.

The Manifold Effect Apparatus:-

From the separate bodies, the particular object to be kept in view is the most rapid and satisfactory evaporation possible, in order to get the greatest possible efficiency from the exhaust and boiler steam used for heating, evaporating and boiling. The more bodies a system has one after another, the greater will be the efficiency of the steam for simple evaporation. Too often, however, several bodies are heated with steam of the same pressure so that the effect is merely that of a single body of the evaporator. In such cases, it is best not to lead the juice and the vapor from one body to another, but to connect them up so that the juice enters in one portion of the apparatus and flows over baffles before leaving the other side, while the steam in the heating space flows in the opposite direction from one body to another. With this arrangement, a greater capacity and easier control of the system can be maintained, provided the juice level is kept the same throughout all the bodies. For the manifold utilization of steam there are definite limits. The total temperature difference, i.e., the difference between the heating temperature of the vapors in the first effect and that of the exhaust steam temperature of the boiling

juice in the last body is at the highest 50°C., because the exhaust steam cannot possess more than ten pounds pressure with the engines and machinery working economically, and the vacuum in the last body cannot be held at much better than sixty centimeters. This total drop cannot be divided into equal parts. There are decreasing limits of drop in each body of the evaporators. The only way to obtain an equal evaporation is to increase the area of the heating surface. On the grounds of practical experience, the temperature drop in the first body, the contents of which boil at 100°C., and over, should not exceed four to five degrees; in the middle bodies, seven to ten degrees; in the thick juice body, the difference should not be less than 15°C. From which it is apparent that it is hardly possible to separate the temperature drops so as to obtain more than six bodies in the apparatus and obtain satisfactory work in sugar factories. In fact, sextuple effects working with exhaust steam, present innumerable difficulties, and even quintuple effects are not generally used in sugar factories as much as quadruple effects, while many places work with the triple effect with or without preheaters.

If all the vapor which is used in the apparatus for boiling and heating were removed, then in every evaporating system all the steam developed in one body would be condensed in the next and the total amount would be recovered on the heating surfaces without any loss.

One kilogram of steam gives, on condensation, different amounts of heat, according to the temperature of the condensed water. It is evident that the condensed water has the temperature of the heating space, and carries off considerable heat from it. The higher the pressure of the heating vapor, the smaller will be the amount of heat lost by condensation, because a greater portion of the heat remains in the

condensed water. With one kilogram of exhaust steam, not quite one kilogram of water is evaporated, but somewhat less, and in the same way in the manifold effect, not two, three, four or more kilograms from the juice, but always somewhat less on account of the loss of heat in the condensed water, which amount is equivalent to the difference between the temperature of the juice and that of the water. But since this quantity is small, it can, as far as practical considerations are concerned, be neglected.

If it is desirable to evaporate the same amount of water in each body of the apparatus, the heating surfaces must necessarily be different on account of the great variations in the transference of heat in the different bodies. As previously noted, there are a number of causes which are more unfavorable to the transference of heat in the thick juice bodies than in the thin, such as viscosity of the juice, the lower boiling point and greater deposition of scale. Under these conditions, in order to obtain the highest possible capacity of the entire system, great care must be taken not to alter other important conditions of the first bodies, in order that the capacity of the system may not be changed.. The means adopted for increasing the transference of heat in the thick juice bodies is to increase the drop in temperature so as to maintain a boiling point as low as possible, with a comparitively small amount of vacuum. If the vacuum increases beyond 60 centimeters, drop in temperature increases very rapidly. With each centimeter of vacuum, the coefficient of heat transference should decrease exceedingly rapidly with the decrease in temperature. Hence, it is hardly advisable to hold the vacuum higher than 60 centimeters; moreover, since such vacuum is difficult to obtain, unless there are large quantities of cold water available, (and the efficiency of the

vacuum pump is very low under such conditions), it is best to maintain practical work at about 60 cm. Since the boiling temperature cannot be decreased further than that corresponding to a vacuum of 60 cm and the temperature of the heating vapor must be increased, it follows that the duties of the other apparatus must be decreased, though the total capacity of the installation is determined by these conditions. These capacities of the different units must be so arranged that the first body will have a very small difference in temperature between the heating vapor and the boiling juice, and the rest of the temperature differences should be divided between the remaining thick juice bodies. A further consideration, to be noted, is that the heating surface of the thin juice bodies must be increased as the temperature differences are decreased, in order to evaporate the necessary amount of water from the juice. While the thick juice bodies need a small heating surface, the first bodies must be correspondingly larger than the last, because the steam used in them is partly utilized for heating the juice for boiling as thick juice. The body from which the heating vapor is to be drawn should be chosen from the size and the heat-transferring-qualities of the heating surfaces in the boiling and preheating apparatus, and also from a consideration of the temperatures at which the juice is to be heated and boiled. When the boiling temperature in the first body is too low for proper boiling and heating, on account of the last bodies being too large and the steam pressure in all the bodies too low,- the pressure can be decreased by the introduction of spray pipes in the vapor lines between the first and second bodies, in order to decrease the pressure of the exhaust-steam and vapors. But, such types of installation are rarely successful without the most careful supervision, and should never be used without regulators to prevent the spraying apparatus from becoming entirely shut off.

The cold raw juice can easily be heated with the exhaust vapor of the last body, since this vapor has a temperature of 60 to 70° C., while the juice is only about 25 to 30° C. This reheating is desirable because it is so cheap and can be done with vapors, the heat from which would otherwise be lost in the work. The size of such a heater need not depend on the size or capacity of the evaporating apparatus, for it is merely a form of surface condensor inserted in the vapor lines.

All other juices need to be heated with steam of at least 90 to 100° C. This must be taken from the first two bodies of the manifold apparatus, or the first body of a triple effect when a thin juice reheater is used. The so called juice boilers or preheaters are merely heating bodies of the manifold system, which are heated with boiler steam of high or low pressure. Their installation is advisable when there is not sufficient exhaust steam for evaporation and it is essential to use high pressure steam for heating purposes. In the preheater, the pressure of the steam can be as high as 3/4 to 1 atm., above the normal pressure, and the boiling point can rise as high as 115 to 120°C without any danger of destroying the sugar or darkening the juices, providing of course, the latter are sufficiently alkaline. Since with high pressure steam, the heating surfaces and steam pipes can be made smaller, they are considered very advantageous. Some factories have installations of two juice preheaters, in which high pressure steam is used in the first, while the second is heated with the exhaust vapors from the same. This installation is most advisable when, through the centralization of the engines, there is an insufficiency of exhaust steam; high pressure steam can thus be made to serve a double purpose before it is added to the exhaust steam to be used in the evaporators. There are, naturally, many difficulties connected with the operation of the juice-boilers in conjunction with an evaporating system, which can only be obviated by proper means in the latter. It is never advisable

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to pump the entire amount of thin juice through the juice boiler, for it is not essential to heat the entire amount to the boiling temperature. Under such conditions, when the juice is drawn into the evaporators, the excess heat is given off in the form of vapor and correspondingly larger amounts of high pressure steam are condensed in the juice bodies; hence, it is best to take only sufficient juice through the preheater to give a final density of 15 to 20 Brix, and the rest of the thin juice should be taken directly into the first body.

Preheaters are sometimes apt to have the disadvantage of variability in their capacity, for example, when the vacuum apparatus is freshly installed, very little time and much heating vapor is used for the first concentration of the thick juice and very little steam is needed for the final-boiling-off. At the same time, it is possible for momentary stoppages to occur in the juice going to the first body with the subsequent lack of use of the exhaust steam. At such times, the preheater needs considerable steam, and in consequence, much must be taken from the boilers while the exhaust steam passes off through the roof. To avoid these evil conditions, the exhaust steam lines should have a by-pass into the steam line to the preheater, which should always be kept open during the usual work. Hence, one line is sufficient for both the exhaust and the juice vapors, which are conducted to the heating and boiling apparatus. The pressure and regulation of the amount of heating vapor can be regulated at the desired point by very simple means in the reheater. The juice is never found to foam badly in the preheater, because the development of vapor is far more regular, and sudden increases of temperature with rapid decreasing pressure and strong foaming are quite unlikely. When the preheaters are used in general steam work in the house, apparatus for regulating the influx of the high pressure steam into the boiling space is not only unnecessary,

but superflous, for strong sudden changes of pressure are impossible and a careful workman only has to watch the guage in the exhaust steam line. Wherever preheaters are used, the entire evaporating apparatus must be of such capacity as to thoroughly evaporate to the proper density the amount of juice which is sent to it regularly in the work. Irregularities which are necessarily incident with certain types of evaporating apparatus can never be entirely prevented in practice. They are in part dependent on the operations of manufacture, for example, varying amounts of exhaust steam used at different periods of the work and the boiling of thick juice to a fillmass. Moreover, it is well known the flow of juice in the factory is never entirely regular. Sometimes the juice runs a trifle slow in the diffusion on account of poor cosettes, or unequal or irregular pressure; sometimes the rate of saturation varies; and at the filter presses runs faster or slower; or the juice accumulates in the storage tanks beyond an extent calculated for it when the evaporating installation is only designed for normal capacity.

The bodies of the evaporating system must be chosen, not only so they will have the proper amount of space in the first bodies, for the purpose of heating and boiling, but they must also be able to evaporate sufficient quantities of water from the juice. In consequence, for temporarily forced work, the heating surface should have an addition sufficient for ten percent above the normal capacity, for all bodies; and there should be a further allowance for the decrease in the transmission of heat due to the deposition of scale on the heating surfaces. But since such depositions occur in large quantities only in the last bodies, the increased heating surface is to be supplied on this basis in these bodies only. While an increased flow of juice calls for larger heating surface in all the bodies of the evaporating system, an increased amount of vapor for boiling and heating, results in increased

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capacity of the bodies in which this increase of vapor occurs. Because this irregular development of vapor effects only the first body and the preheater, it is not necessary to figure on the heating surface for the largest use of steam; and it is quite satisfactory to figure on the average amount of steam which can be used on the heating surface, providing care is taken to anticipate any possible increase in the temperature of the heating vapor. Since the capacity of the evaporating apparatus is within normal limits proportional to the temperature difference, the normal amount of which rarely exceeds 6 to 8°C, an increase in the temperature of the heating vapor of 2 to 3°C., (corresponding to a pressure difference of 2/10 of an atmosphere) would increase the capacity of the apparatus 1/4 to 1/3. This increase should be possible in order to cover the great irregularities in the use of steam in the boiling and heating stations.

The manifold effect system is quite flexible and, as a rule, every change in the evaporating conditions adapt themselves rapidly to the best conditions possible under the circumstances. The greatest variations are due to the temperature differences in the single bodies. It is these changes, with corresponding variations in the coefficient of heat transmission, which alter the capacity of the system. All calculations on the heating surface must be based on the known conditions of evaporation, the values of which remain unaltered by other conditions later in the work. The great adaptability of the manifold effects is due in part to the large number of complicated conditions which govern the operation. These can never be wholly taken into account from a theoretical stand point.

The bodies of an evaporator should be placed in a line, with the separate bodies so arranged that they can be used as the same units, thus decreasing the number of effects. Each body, when Coffer shaped,

has its particular heating-tube-space fitted with vertical tubes. The heating space is connected by means of proper channels with the main steam line and the vapors pass from one or more openings through the usual cooking space into the vapor lines. The juice circulation is thus quite satisfactory, for the single tube heating systems give a sufficiently broad space in between the walls. In these types of apparatus, increased capacity can be made with little cost and few changes in construction, and in the same way, changes of the units will allow changes in the heating surfaces in different bodies, when this is found desirable.

The basis for calculating the heating surface depends on the coefficient of transference of heat. With the usual types of the vertical or horizontal apparatus, the following figures can be used for practical work:----

With the quadruple effect, the coefficients in the first body are: In I. (and in the preheater) 40 to 50; in II. 30 to 40; in III, 20 to 30; in IV. 10 to 15.

With the t. iple effect: In I. 40 to 50; in II. 30 to 35; in III. 12 to 15.

Of course, it must be understood that these figures are only applicable during proper operation of the evaporators. If the amount of thin juice and available steam for heating and evaporating are determined, all the conditions for calculating the size of the required heating surfaces are at hand (See Appendix II). It is very important in these calculations not to contemplate too high a temperature for the exhaust steam in the first body. The heating surface will then be sufficiently large for the proper capacity and manifold effect evaporator, and for the correct incidental conditions. The evaporating station should have a capacity sufficiently large to utilize all the

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With the triple effect: In I. 40 to 50; in II. 30 to 35; in III. 12 to 15.

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steam in the factory for heating purposes. Experienced calculations have shown that the steam economy is better the more fully the steam from the evaporating apparatus is used for boiling and heating; therefore, under these conditions, no high pressure steam should be used. In this manner, with proper usage of the exhaust vapors for boiling and warming, better results are obtained with the quadruple than with the quintuple or sextuple effect evaporators, in which the use of exhaust vapors is necessarily careless. Even a triple effect can be used to advantage when fuel is cheap.

In factories with properly designed evaporator installations, the total steam used per 100 kg of beets is about 60 kg., including the cooling losses. No factories use more than 70 to 75 kg., and this total amount of steam should be used (either as exhaust steam from engines or high pressure steam from the boilers) in the first body or the preheater, unless it is advisable to inject steam into diffusion lines. The use of steam can be curtailed by enlarging the bodies of the evaporator station, or by increasing the use of the steam in the same, or by raising the temperature of the vapors for the reheaters. In each change of installation, calculations should show a sufficient saving in fuel to warrant any increase or repairs on the station.

A theoretically interesting, although impractical system of steam utilization, by means of which steam can be decreased below 60 kg per 100 kg beets, is that which depends on removing the vapor developed in the first or second bodies, and increasing its pressure by means of pumps to that of the high pressure steam, so that it can be reused as such. Naturally, this method can only be employed when the compression pumps are operated by water power, but the evil of extreme

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In factories with properly designed evaporator installations, the total steam used per 100 Kg of beets is about 60 Kg., including the cooling losses. No factories use more than 75 to 75 Kg., and this total amount of steam should be used (either as exhaust steam from engines or high pressure steam from the boilers) in the first body or the preheater, unless it is advisable to inject steam into diffusion lines. The use of steam can be curtailed by enlarging the bodies of the evaporator station, or by increasing the use of the steam in the same, or by raising the temperature of the vapors for the reheaters. In each change of installation, calculations should show a sufficient saving in fuel to warrant any increase or repairs on the station.

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superheating in the compressed steam has to be contended with. Superheated steam is entirely impracticable for heating purposes in the evaporators, because it is not cooled sufficiently at saturation temperatures, as normal gas, and gives up its heat very slowly on the walls of the heating tubes. The superheat is not taken up sufficiently rapidly, even by means of water sprayed into the vapor lines; the compression pumps are also heavily charged with oil, and the compressed steam carries much of this material, which collects on the heating tubes and seriously retards the transference of heat. The disadvantages of this system can be obviated by injecting high pressure steam into the low pressure lines. By means of this apparatus, exhaust vapor of low pressure, or even high pressure steam, can be increased at least 1/2 atmosphere pressure without losing any heat and without any undue amount of super-heat in the steam mixture. The amount of exhaust vapor which can be brought to a higher pressure in this manner depends on the pressure of the boiler more than the increase of pressure obtained. To increase the pressure of 1 kg of exhaust vapor by 1/2 atm., 2 kg of boiler steam of about 6 atm are essential. In the transfer, as the evaporator station needs high pressure steam, it is best to use steam in the form of a steam spray apparatus, the installation of which is comparitively cheap. It is important, in working with this apparatus, to use boiler steam of full pressure. But since the amount of boiler steam essential is very variable, it is advisable not to install a steam spray apparatus any larger than for the required capacity, it being better to install two small apparatuses, the combined capacity of which is equal to the full amount necessary for the work. In calculating the capacity of this apparatus, it should be made sufficiently large to heat the exhaust vapor from the second body to the same temperature as that needed for the preheater. At the beginning of the work, when the evaporating

apparatus is not in use, (during Sunday pauses or breaks in the work) direct high pressure steam must be used for reheating and boiling, and the steam valves on the apparatus should be carefully watched to prevent any misuse; they should be provided with locks, or have the hand-wheels removed when not in use. It is advisable to have only one large valve on the exhaust steam or vapor lines to the evaporator, instead of a number of small ones, and to inject boiler steam through these lines. A single valve can be watched better than several small ones.

It is generally maintained that there are no great losses due to the destruction of sugar in the evaporating apparatus unless the boiling temperature exceeds 115 to 116°C., or the juice is not sufficiently alkaline. Small losses do certainly occur, but in normal work, these do not exceed a hundredth part of one percent. These sugar losses do not increase with the temperature, but with the duration of the boiling of the juice at a high temperature; for every hundred parts of sugar in the juice there are, for example, .14 parts of sugar destroyed for every hour of boiling at 100° C; at 110°, .163 parts, and at 115°, .175 parts. Hence, if juice were to be boiled in one evaporator for half an hour at 115° C., and in another at a lower temperature, say 100°C., for one hour, there would be more sugar destroyed in the latter than in the former.

Long delays of the juice in the evaporators occur when the amount of juice contained in the bodies is excessive, or when the temperature conditions are insufficient for proper boiling. The juice contents are greater than necessary when the boiling is carried on with a high juice level, or when there is too much tube volume in vertical apparatus, or too much juice room within the horizontal apparatus. In consequence, the juice level should be maintained as low as possible during boiling, and the apparatus should be so constructed that the extra space is merely that sufficient for the proper circulation of the

apparatus is not in use, during Sunday pauses or breaks in the work) dirt heat high pressure steam must be used for reheating and boiling, and the steam valves on the apparatus should be carefully watched to prevent any misuse; they should be provided with locks, or have the hand-wheels removed when not in use. It is advisable to have only one large valve on the exhaust steam or vapor lines to the evaporator, instead of a number of small ones, and to inject boiler steam through these lines. A single valve can be watched better than several small ones.

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juice. The bad habit of filling the apparatus full of juice when there is an excess of thin juice, or the thick juice is not taken away sufficiently rapidly, should be carefully avoided, for this has a tendency to decrease the capacity of the apparatus at the very moment when attempts are made to increase it. Too great a retention of the juice in the evaporating apparatus, when the heating surfaces are too large for the quantity of the thin juice, is injurious irrespective of irregularities of the work. The boiling point should never exceed 120°C in any type of apparatus, certainly not for any length of time, because for every degree in excess of this temperature, the destruction of sugar increases very rapidly. If on any ground whatever, thin juice must be boiled neutral or weakly acid, (a method always to be depricated) the boiling temperature should never exceed 100°C., and even this is critical. Under such conditions it is impossible to obtain an economical utilization of steam.

The perfection of the work of the evaporating apparatus depends upon the following conditions:--- -

Firstly: That the steam shall be regulated by the quantity of thin juice.

Secondly: That the pressure in the first body and in the preheater does not exceed the previously described limits.

Thirdly: That the vacuum in the thin juice body should be maintained as high as possible.

Fourthly: That the juice level in all bodies should be as low as possible.

Fifthly: That the thick juice should be drawn from the last body at the same rate and the same density.

If these conditions are carefully maintained, all the other conditions will properly regulate themselves. Since the exhaust steam from the engines is rarely sufficient for evaporation, it is seldom necessary to throttle the inlet valve of the same. With, however, a

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lack of juice the valve must be closed and the steam must be blown off through the safety valve. In such cases, it is never advisable to draw water into the juice in order to prevent blowing off of steam through the roof for the juices are only injured thereby. The pressure in the heating space of the first body should not exceed the back pressure of the exhaust steam which, with too great a counter pressure, decreases in its rate of flow and does not allow economical work. The amount of boiler steam conducted to the evaporators from the preheater must be regulated by the pressure in the boiling space of the first body.

In the thick juice bodies, the vacuum should be maintained at a constant height for any decrease lowers the temperature in the first body. At the same time, it is essential to maintain the thick juice at a constant density, for any increase above 60° Brix calls for a rapidly increasing boiling point, and the viscosity of the juice becomes noticeable immediately in the increase of pressure in all the previous bodies. By the increase of the boiling point, the working temperature conditions are decreased; on account of the increased viscosity which decreases the coefficient of heat transference with a thick juice of 50 to 60° Brix, this is about two-thirds; with a thick juice of 70° it falls to about one-third of the coefficient for water. The statement that the specific heat of the thick juice influences this coefficient is false. A regular density of the thick juice is very advantageous and in consequence, the density should be determined frequently by spindling, or better still by automatic regulating devices. A simple and practical method is the spindling of the juice as it comes out from the pressure line from the pump, by means of a spindle cylinder with a float valve through which the thick juice runs continuously.

In order to withdraw the thick juice from the evaporators, juice lifters are rarely used. Pumps should be installed in every

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case in order to obtain a constant draw of juice, and thus obtain a thick juice of even density. Pumps work best against the vacuum of the apparatus when they are placed as far below as possible, in order to have the column of juice counter-act part of the effect of the vacuum. The transference of juice from one body to another should be uninterrupted and regular. A careful worker learns very rapidly how to regulate the transfer valves so their position rarely has to be altered, as long as the juices enter the evaporator regularly. The transfer pipes should never enter the upper heating space of the apparatus, but the under portion beneath the heating tubes and should be introduced through perforated pipes. Juice in being transferred from one body, to another with a lower pressure is overheated, for the latter, on its entrance, developes suddenly a very large amount of steam, which, when conducted into the upper portion of the heating surface is sprayed over the apparatus and is the cause of considerable loss of sugar through entrainment. If the juice is led under the heating tubes, the ensuing bubbles and vapor of steam are quite advantageous in increasing the circulation. In order to precisely regulate the juice level, stand glasses should be so installed both below and above the heating spaces. Juice guages which stand entirely above the heating tubes are of no advantage. Large eye and light-glasses, through which one can note the contents of the evaporators, are quite essential in all types of apparatus. When these precautions are followed, normal conditions can be readily obtained, in which the pressure of vacuum conditions remain the same in each body, as long as the exhaust steam pressure and vacuum of the condensor are constant. Variations from these rules are the cause of decreased capacity and stoppages in the work due to difficulties of evaporation. If these variations occur regularly at the end of the week in such a manner that with a constant vacuum in the thick juice body the pressure in the previous body increases, it is a sign of deposition of scale on the heating

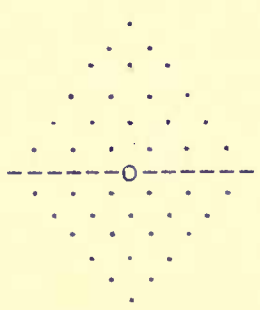
tubes, and this indicates, to some extent, the strength of the fluid with which the evaporators must be boiled out and the time which will be necessary. Further disturbances in the pressure conditions occur when the condensed water from the heating tubes is not fully withdrawn and thus decreases the heating surface. In order to prevent these difficulties, water guages should be placed within the heating spaces. The removal of condensed water from the heating spaces in which the steam has a pressure greater than 1 atm., can be accomplished by means of traps, but great care must be taken that these discharge properly without allowing steam to blow through them. The water condensed in the

thick juice bodies, is either pumped or removed in the tail pipe in the form of a water column, which is sufficient to overcome the vacuum in the heating space; this necessitates a height of six to seven meters. At the same time, condensed water from other apparatus is led to this container and pumped from there to points where it is to be used, though it is best not to mix this hot water with cold. That which is over 100° C., should be used for feed water to the boilers, while the rest should be used for diffusion, sweetening off the filter presses, slacking of lime, etc.

In some factories, attempts have been made to utilize the heat from the condensed water for evaporation by running the water from the heating space of one body to that of the next of lower pressure, in which manner the excess heat is given off in the form of vapor. In this manner all of the water finally collects in the heating space of the thick juice body, from which it drains with the low temperature of this heating space. When this method is used, drain lines must be utilized in order to prevent any possible accumulation of water. Any further advantage is questionable, for the heat which is thus utilized in the evaporators, is lost for boiler purposes.

The pressure conditions can also change when the juice starts to foam. The formation of foam is advantageous within certain limits, when the juice levels are maintained properly, but if the foaming becomes too violent the heating surfaces are no longer satisfactorily wet over their entire surfaces and every dry spot is inactive; hence, with violent foaming, an increase of pressure occurs in the heating space. To precipitate the foam, fats must be put in the apparatus; these should be of high viscosity so as to use as small an amount as possible, because the ensuing lime soaps and undecomposed fats injure the filtration of the thick juice. To insert fat into the apparatus, an oil pump with a butter valve should be installed in the vacuum space of the boiling body.

A low vacuum in the last body and high pressure in the first is a frequent occurence in the beginning of the campaign on account of the inequalities in the density of the lower vacuum working bodies and evaporator lines, due to influx of air which prevents the condensation of the steam in the condensor, and is the cause of overloading the air pump. Such irregularities can be detected by the sucking sound of the air or by means of a flame, and can then be remedied by cement or putty. Changing the simple methods of working is never essential; changes in the practical workings of the evaporators are rarely successful in practice, and such propositions, as a rule, are only made upon paper and are not experimented with, nor their feasibility not demonstrated by actual practice.



CHAPTER XIII.

CONDENSATION OF THE VAPORS.

For a number of years the duplex effect evaporators and their vapors were used for heating and boiling, and in consequence, large quantities of vapors from the juice were gathered in the condensors. With the present type of evaporating apparatus, comparitively small amounts of vapor reach the condensors. Where heating and boiling occurs, there is, naturally, a condensation of steam. Apparatus to accomplish this purpose serve also as condensors, usually surface condensors. When speaking of condensors in sugar work, the term is applied only to the spray condensors which condense the vapors alone.

Of 100 kg of water evaporated by expansive heating of the juice with vapor and boiling in the quadruple effect evaporators, (which represent about the amount which must be evaporated from the juice of 100 kg of beets), only 10 kg are conveyed as vapor from the thick juice bodies to the spray condensors, while a portion of these vapors are sometimes used to heat the raw juice and are condensed in the preheaters. The remaining 90 kg of water are condensed on the heating surfaces of the reheating and boiling apparatus, being precipitated as pure, somewhat ammoniacal, condensed water. Besides the vapor from the thick juice bodies, that of the pans must also be condensed. According to the density of the thick juice, from 10 to 15 kg of water must be evaporated per 100 kg of beets. And as much again must be evaporated in the evaporator bodies, with the differences that the evaporation in the latter is distributed equally throughout the 24 hours. In consequence, the condensor capacity of the former must be sufficient to take care of the maximum development of vapor.

The vacuum pumps are of either the "dry" or "wet" type. They remove the noncondensable gases and the hot water used in condensation.

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The wet pumps have the disadvantage of precipitating scale from the hot water. The counter current condensors do not show this failing because the cool gas coming in contact with the hot water is rewarmed, occupying a larger space but thereby diminishing the capacity of the pump. Hence, in sugar factories, the dry vacuum pump is favored, with high condensors from which the water flows through a barometric column. The condensors are nearly all of the counter current types in which the vapors enter at the bottom and come in contact with falling water. The failings of these condensors which gave many difficulties in their earlier installations, and caused the use of the more unsatisfactory direct current condensors, were namely; the blocking of the counter current condensors, thereby causing irregular work and sending large quantities of water into the vacuum pumps. These difficulties could have been obviated by raising the height of the condensor and increasing its cross section, also arranging the spray holes sufficiently far apart, particularly in the lower portion where the vapors enter. It is also important to bring the vapors in sufficiently high from the bottom, so that they will have space enough to travel a short distance with the falling water. By these means, the condensors are rarely blocked. The inner arrangements are quite varied; in some the water runs over troughs or shelved plates, in others it falls in the form of a spray or fine drops, while in others it flows over intersupposed baffles. For sugar factory practice, they all work satisfactorily when they have sufficient cold water injected, and give a sufficient vacuum, that is about 60 cm., which is essential for boiling in the pans.

Condensors work satisfactorily developing a vacuum of 60 cm., when the temperature of the tail pipe water is not more than 10°C. more than that of the vapors, and when the gases drawn from the pump are of the temperature of the spray water. The condensors should be controlled

by the insertion of thermometers in the tail pipes and vacuum pipes near the pumps; the temperatures indicate quickly whether or not the correct amount of spray water is being injected, and indicates as well, the action of the vacuum pump. The tail pipe should have a straight fall of at least 10 m. from the bottom of the condensors to the upper surface of the water in the seal tank. This height should be maintained whether or not a complete vacuum is sought, in order to make full allowances for any shrinkages of the column of water in the pipes. The tail pipe should have a sufficiently large diameter, particularly with waters which precipitate much scale, so that the pipes will not become entirely closed during the campaign. Any cleaning during the campaign, should be avoided, not only because of the necessary delay but because the connections should not be broken during the work.

The temperature of the tail pipe water depends, of course, on the temperature of the spray waters. Under usual conditions when the vapors are of about 62 to 65°C., and the temperature of the tail pipe water about 10°C., and the spray water about 10 to 15°C., 15 kg. of water are used per kg. of vapor, which is, on 100 kg. of beets, about 150 kg. for heating, and 150 to 225 kg. for evaporation. With the increase of the vacuum, the variation in temperatures between the vapor and the spray water decreases, and the quantity of injected water must be increased. It is only possible to calculate the amount of condensor water when the amount of vapor to be condensed is constant. The amount of water used is extremely variable when each evaporator has its own condensor and vacuum pump. The supervision of such an installation is extremely difficult, and the costs of construction are high. Some factories have gone to the other extreme of installing one central condensor and vacuum pump; this has the advantage of the use of a constant amount of water and a single large pump corresponding to its capacity.

CHAPTER XIV.

THE SATURATION AND FILTRATION OF THE THICK JUICE.

The juice thickened in the evaporators has a brown color and is full of fine precipitates which separate out on concentration. The alkalinity depends on that of the juice and its properties; the more ammonia, amides, albumens, invert sugars and lime salts the thin juice contains, the more the alkalinity is apt to decrease on evaporation. When such a decrease does not occur, a thick juice of 60 Brix should have an alkalinity of 5 times the strength of thin juice of 12 Brix, though the alkalinity of the thick juice is only 3 or 4 times greater than the thin juice, so that the rest is distilled off in the form of ammonia, or else is neutralized in such a manner that the alkalies unite with the decomposition products of the nitrogen, invert sugar, and organic lime substances. The color of the thick juice is darker than it should be from the concentration alone, which is readily proved by diluting the thickened juice to the density of the thin juice; the color will generally be found to be darker than that of the unboiled material.

The alkalinity of the unsaturated thick juice, should be maintained between .07 and .05%. Since a juice as strongly alkaline as this cannot be readily boiled, it should be saturated with carbonic or sulphuric acid. In some factories, the alkalinity is decreased to almost the point of neutrality, while in others, it is kept to about .03 to .04%. If the alkalinity decreases very much on boiling, it should be maintained sufficiently high in the thick juice, so that the fillmass, the first sugar, and the syrup, should remain sufficiently alkaline to give a decided red color upon the addition of phenol. If the thick juice holds much free alkali and no lime salts, it can be saturated to nearly the point of neutrality, and there will be little likelihood of the alkalinity deteriorating. The disadvantages of higher alkalinities are poor

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boiling of the thick juice, and high ash sugars. The boiling of the thick juice is very tedious and slow, when the alkalinity is due to CaO, also in the presence of any hot saccharate. With an alkalinity of .03 to .05, this is not the case, for the alkalinity is very apt to be due to carbonic acid, caustic alkalies, ammonia, or organic bases, but an increase in the ash content cannot always be attributed to the alkalinity. Under favorable circumstances, saturation of the thick juice with carbonic or sulphuric acid, precipitates the lime salts in conjunction with considerable quantities of the soluble alkali salts. At most .03 to .05 gm. of lime are precipitated from 100 gm. of thick juice, which holds a total ash of about 2 gm. or about 1/2 to 2% of the total ash, an amount which is hardly noticeable in the sugar. But since the amount of carbonic and sulphuric alkalies which decompose, with the limesalts, is never complete, small portions of lime are always reprecipitated in saturation and redissolved in filtration, working to neutrality is hardly apt to increase to any noticeable extent the yield of sugar. The feature of neutrality is not nearly as important as the maintenance of a proper temperature in the saturation, and above all things a thorough filtration, in order to decrease the ash content of the thick juice.

The thick juice from the evaporators has a temperature of that of the last body, that is about 70°C. Before saturation, it must be heated nearly to boiling, which is best accomplished with exhaust steam. Injection of steam is not advisable, since it dilutes the juices too much. The saturation of the thick juice is best accomplished in tanks into which the thick juice is pumped constantly, just sufficient running off to keep up with the capacity of the filters, the carbonic or sulphuric gases being conducted into the tank in a steady stream. An addition of lime to the thick juice is rarely made and is entirely superflous when the thin juice is maintained at the proper alkalinity.

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From juices which hold an alkalinity of .07 to .15, there is on boiling alone in the saturation, a very noticeable precipitate of fine grained particles, which smear the filter cloths and retard filtration. If on the other hand, the thin juice is saturated too far, the thick juice will yield on saturation a poorly filtering material. Under such conditions, a slight addition of milk of lime is an aid, but thick juice which comes from the evaporators with high alkalinity filters the best. When lime is added to the thick juice, it should be allowed to act for some time at a high temperature. The continuous carbonation can be used with this process.

For the purification and saturation of the thick juice. it makes no difference whether carbonic or sulphuric acid is used. The use of sulphurous acid has the advantage of giving a clearer juice and sugar, and probably leaves a smaller amount of soluble salts in the juices. The use of sulphurous acid should be applied only to the saturation of the thick juice, and is very commendable in this portion of the processes of the beet sugar house.

For the filtration of the thick juice, the same apparatus is used as in filtering the thin juice, but since a somewhat higher pressure is used for the former, filter presses with filter plates of wood or sand or coke-filters are used. The first thick juices, which flow rather cloudy from the filters, are returned to the thin juice saturation, and only the clear juices are conveyed to the thick juice storage tanks. The cake which collects on the cloths cannot very well be sweetened, for presses are rarely provided with sweetening off apparatus. When this cake contains a large percentage of sugar, it should be returned to the saturation tanks. It is doubtful whether or not it is advantageous to sweeten off the cloths, for the juice obtained from them seems to spoil

very quickly; in all events the losses in the cake and the cloths are so small that they can hardly be taken into account.

In most instances, the thick juice, filters fairly well, in some cases however, much difficulty is experienced, particularly when the juices are denser than 60° Brix; in such cases it is best to saturate and filter the so called middle juice, that is the juice from the third body of the evaporators. The juice of about 30 Brix is taken to the saturation tanks and treated in the manner of the thick juice, and then returned to the last body where evaporation is completed. After being concentrated, it again becomes cloudy, but the great majority of precipitates being removed, no difficulty is experienced in final filtration. This method is to be recommended when the juices deposit a great deal of scale in the evaporators.

The filtration of the middle juice is usually accomplished in closed filters of either the coke, bonebiack, or filter press type. Frequently the juice is saturated in the evaporators automatically, by conducting sulphurous acid into the boiling juice, but this method is difficult to control and is in consequence not advisable.

There are no definite conditions or proportion of a thick juice which will determine the manner in which it should be boiled and worked as a sugar. A juice of high purity generally boils well, but in working poor beets when the thick juices have a purity of only 80, neither the analyses nor the color are sufficient for any conclusions. It is frequently thought that the amount of lime or of lime salts present are a good indication of the "workability" of the juice, but in reality this depends on the combinations of the lime salts. A large amount of such salts is an indication of juice obtained from poor beets with energetic liming and little improvement. It is entirely wrong to conclude that

the color is a good indication of the quality of the juice, for clear thick juices, particularly those which have been bleached with chemicals, become sour quickly, while the dark juices often give the best sugar products.

When the thick juice is handled properly, there is little likelihood of obtaining anything but good material, but there is little possibility of purifying the thick juice when no improvement is obtain-in the thin juice, nor is it possible to correct mistakes in the thick juice which have been made in the handling of the thin liquor.

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CHAPTER XV.

BOILING OF THE THICK JUICE.

The filtered thick juice is boiled to a grain in a vacuum apparatus which serves the double purpose of crystallization and boiling. It must be adapted to both purposes, particularly the proper crystallization of the sugar. In general, all pans have the same shape and appurtenances, in order to give good circulation and easily manageable fillmasses. The vertical type of apparatus is usually employed with a conical bottom. For heating, numerous superimposed coils are used, or horizontal radiating tubes, sometimes heating surfaces with short broad heating tubes, sometimes vertical tubes are used, all of which conduct the steam and the condensed water through the pan. The horizontal type of vacuum pans approximate the designs of the simple evaporator with a discharge opening in the bottom. All heating surfaces should lie as close to the bottom as possible so that they are entirely covered with the juice from the beginning of the operation.

The heating tubes are principally of iron, since this metal is attacked less vigorously by ammonia gas than brass or copper, though it has a smaller conductive value of heat, but the difference is so small that it can be neglected. In the pans, the ammonia vapors act more injuriously on the heating tubes than on the evaporators, because the circulation is small at the end of the boiling around the heating surfaces in the pans, and the ammonia has greater opportunity to act for a longer period on vulnerable spots.

The discharge openings of the pans are closed, as a rule, by means of a ball. When the fillmasses are cooked with a great deal of syrup, so that they remain comparitively thin fluids, the openings are closed with a sliding gate. The earlier use of the steam mantle on the under surface of the double bottom is discarded these days, for no particular advantages can be ascribed to it, though it was thought that

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The discharge openings of the pans are closed, as a rule, by means of a ball. When the filmasses are cooked with a great deal of sirup, so that they remain comparatively thin fluids, the openings are closed with a sliding gate. The earlier use of the steam mantle on the under surface of the double bottom is discarded these days, for no particular advantages can be ascribed to it, though it was thought that

by heating the lower layers, bubbles of steam formed on the bottom which aided the circulation of the fillmass, and hence, acted favorably on the boiling and crystallization. The double bottom has no particular value, because the conductivity coefficient of the same is very small.

The rest of the equipment of the pans must be such that the boiler can readily control the boiling and note any unusual conditions, and have the means to remedy them. In order to obtain an average sample of the contents of the pan, the proofstick must be placed in the right position so as to obtain a sample from a portion that is in thorough circulation. Sight glasses must be arranged so as to thoroughly illuminate the interior of the pans. The thermometer must have a shaft sufficiently long to reach well into the interior. A mercurial barometer should be used to indicate the vacuum. The juice and syrup inlets must be sufficiently large and have proper position. The crystallizing troughs, underneath the apparatus, should be provided with the proper distributing gates. The heat should be furnished with high or low pressure steam, and valves controlling the coils should be readily accessible. The pressure of the steam, both at inlet and outlet, should be indicated to the boiler by means of manometers. The condensed waters from the coils should be taken away in traps, and there must be proper arrangements for conducting away the ammonia vapors. There should be several valves for drawing hot or cold water into the pans. It is very important to have a perforated coil in the bottom of the apparatus in order to blow live steam directly into the mass to start the circulation. After the pan is dropped, these coils can be used to steam out. The sizes of vacuum pans are extremely variable. One large pan naturally serves the purpose of several small ones, but for the work of the entire factory, one single large vacuum is not advantageous (as previously indicated in the chapter on evaporation), for at the beginning

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of the boiling, more steam is needed than the evaporators can furnish. The further the boiling proceeds the less thick juice is drawn in, and the less steam is used, so that the boiling finally takes too little steam from the evaporators and the thin juices are brought to a standstill. Henco, every factory should have at least two vacuum pans of average size, which should be worked alternately in order to take the thick juice regularly.

There are no definite conditions determining the size of the heating surfaces of the pans; they cannot be calculated as in the evaporators, because the conditions governing the conduction of heat during the boiling, undergo extreme changes at different times, during which varying amounts of water are evaporated. Then too, it must be noted that the boiling in the pans has, as its principle object, the crystallization of sugar. As large a heating surface as possible should be used, for it can never be injurious providing it is placed in the bottom of the pan and does not injure the circulation. In all cases, heating should be done rapidly in the beginning, and low pressure exhaust steam can be used. The conduction of heat to the mass, as well as the evaporation, depends not alone on the size of the heating surfaces but also on the amount of steam, and pressure of the same, conducted into the coils. With heating surfaces, only a portion of the same are effective. Where the design will allow, it appears to be advantageous to divide the coils, giving a separate steam inlet and trap to each. This arrangement allows a better regulation of the steam, in order to obtain a proper crystallization of the sugar. Pans of a capacity of 20,000 to 50,000 kg. fillmass, in which size they are usually built, have heating surfaces of from 80 to 150 sq.m.

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surfaces are entirely effective, circulation is good and good sugar is produced. Because a boiler obtains poor results with a new vacuum pan, and good results with an old one, it is not reasonable to conclude that the new apparatus is faulty. The art of boiling is learned empirically and must adapt itself to each new type of apparatus and the properties of each particular fillmass.

The art of boiling consists of building the proper number of crystals in the thickened juice, and of allowing only these to grow without the formation of new grain. The boiler reaches this goal by noting the properties of the sample drawn from the apparatus, and drawing conclusions as to the concentration of the syrup. It is not necessary to describe here the means which the boiler uses for this purpose. These things can only be learned by practical work and every boiler has his own methods. That which is essential and which determines the right or wrong of the details of the art, is a thorough knowledge of the important minutae of boiling.

In order for a sugar solution to crystallize and for the crystals to grow, the solution must be supersaturated. A sugar solution is saturated when at any definite temperature, it will not dissolve any more sugar, nor crystallize further on grain that is present. The higher the temperature of the solution, the more sugar it will dissolve in one part of water. If a saturated solution is evaporated at the temperature of saturation, sugar will not crystallize immediately but remains dissolved and the fluid becomes supersaturated. The purer the supersaturated sugar solution, and the more crystals there are present, the more rapidly will the sugar crystallize out of the solution. Impure sugar solutions take a longer time before they begin to crystallize, and must be more highly saturated before the crystals will separate out or grow, proportionately so as the amount of organic impurities increase.

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If at a given temperature, the quantity of sugar dissolved in one part of water, in a saturated sugar solution, is designated as Z; and the amount which at the same temperature is dissolved in one part of water, in a supersaturated solution, is Z_1, the supersaturation-coefficient $c = \frac{Z_1}{Z}$. This coefficient is also the number which gives the number of parts more sugar soluble in one part of water in a supersaturated solution than a saturated solution at the same temperature. This supersaturated coefficient is of primary importance in the crystallization of sugar, whether in boiling or working the fillmass or syrup. While other circumstances are of great importance for the crystallization of the sugar, as for instance, the viscosity, which changes with the temperature, the supersaturation coefficient is still independant and of great importance. Though for boiling or crystallizing, high or low temperatures are important for the graining and growth of the crystal, the saturation coefficients are within practical temperature ranges, the same for syrups and juices of the same purity, and only change with the latter. Supersaturated coefficients on graining are larger or smaller, according to the number of crystals in the solution and the ease of crystallization. For a regular crystallization, a supersaturation of the dependent temperatures should be the same throughout the entire crystallizing mass. During the boiling, the supersaturation is altered by extreme heating on the coils so that a supersaturated solution starts the building of small new crystals, while near the thick juice inlet, the unsaturated solution redissolves the fine grain unless the thick juice is immediately mixed with the fillmass. In consequence, the circulation of the mass in the pans must be of the very best. The design of the apparatus and the coils should be such as to offer absolutely no hindrance to the circulation. No construction can guarantee a positive circulation of juice; for this purpose, the mechanical energy which is

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developed during the boiling, by the ascending bubbles of vapor is essential. The developement of steam on the heating surfaces is smallest when the circulation of the mass should be at its greatest, namely, at the end of the boiling. Therefore, appliances are useful which, at the proper time, give the fillmass a regular and positive movement. Stirrers, scrolls etc., have been found very satisfactory for this purpose in the working of the second products; though for boiling thick juice, they have been used but little because the space in the old apparatuses was too limited. In the newer constructed types, mechanical stirring devices are employed. Movement by means of free injected steam is very important for boiling. The bubbles of steam arising from the distributing apparatus, in the bottom, stir the fillmasses in all portions, even on the heating surfaces and act far better than mechanical stirring devices, so that there is no possibility of any local supersaturation or overheating. In consequence of this method of stirring the fillmass, the developement of fine grain is easily prevented. In order to distribute the thin juice as rapidly and fully as possible in the mass, it is injected in the bottom of the apparatus so that on account of its lighter specific gravity, it will rise and thoroughly mix with the mother syrup. The mixing is accelerated and the thick juice is drawn in hot, so that its temperature is above that of the boiling point of the mass. In this case, as soon as the juice enters the vacuum pan, bubbles of steam form rapidly, which aid a quick circulation. The thick juice should not be lower in temperature than the boiling point of the pan, for it not only mixes poorly, but cools the fillmass and tends to form a fine grain.

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the growth of the crystals to draw thick juice into the pan very rapidly. The more the juice is supersaturated, and the greater the circulation, the sooner and better the crystals form. Under such conditions, the less grain one desires to build, the less thick juice should be thickened and the less fresh juice drawn into the pan. The supersaturation should be used to control the size of the grain in conjunction with the regulation of the addition of the thick juice. The smallest practical value of the supersaturation coefficient is 1.2, for building grain in thick juice of 90 to 92 Purity. With lower saturation, too much time is consumed before a sufficient number of crystals are developed, and there is considerable danger of redissolving the grain in the fresh thick juice. The highest supersaturation coefficient should not be above 1.5 to 1.6, for at higher figures there is a superabundance of grain.

As soon as sufficient grain is formed, the boiling should be carried further, keeping only the grain that exists and causing it to grow. As long as the crystals are small and a granular sugar is desired, the surrounding syrup, or mother syrup, should be kept only slightly supersaturated. Since this syrup approaches the purity of the original thick juice, it has most of its properties, and on addition of fresh thick juice with the supersaturation coefficient of only 1.2, will start to form grain, in consequence, it is best not to reach this figure.

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CHAPTER XVI.

WORKING OF THE FILLMASS.

There are no definite rules for the regular crystallization of the fillmass after it has been put into tanks or mixers. The only warning that can be mentioned is that the cooling must not be too rapid. As previously stated, a portion of the sugar is crystallized directly from the mother syrup, portions crystallize anew as the fillmass cools off, while other portions of sugar are added to the other crystals, increasing their size; of course, small new crystals do little towards increasing the yield. An increase of yield can be obtained by working the fillmass in either tanks or crystallizers, but as in all other methods, great care must be taken to obtain the fillmass in a satisfactory condition for centrifuging.

In tank work, the large lumps of fillmass which cling together and hold considerable syrup, should be broken up and mixed with hot or cold syrup, according to the degree to which the fillmass has cooled. If there are considerable quantities of small crystals in the form of flour, they should be carefully dissolved with a sufficient amount of hot dilute syrup in order not to retard the centrifuging. There is no other method of determining the quantity of syrup to be added than that obtained on good or bad centrifugal work. It is best to pay the workmen on a tonnage basis of sugar produced, so as to have the men properly regulate the amount of thin and thick juice to be used in washing.

The first principle of good crystallization in crystallizers, depends upon the regulation of the temperature. For good centrifugal work, the fillmass should be dropped at about 40 to 50° C., sufficient water or diluted syrup being added so that the mass remains plastic. Previous to the tank work, sugar-mixers are only advantageous in giving a cleaner product in the sugar-house, though the yield sometimes is a trifle greater, and the green syrups of a somewhat higher purity; with

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either method of work the purity of green syrups is rarely under 78 to 80 per cent.

A rational working of the fillmass can be obtained by working up the proper amount of syrup with systematic regulation of temperature and concentration, and it is only under such conditions that the yield of sugar from the fillmass can be brought to the desirable point with a correspondingly low purity of green syrups. The fillmass work is based on the theory that every syrup which is not too highly supersaturated, will yield just a sufficient amouht of crystals for the nucleus of other crystals, thus causing the weakly saturated syrup to become highly saturated on cooling. The problem also depends on arranging the cooling of the fillmass so that the supersaturation-coefficient of the mother syrup does not reach the limit at which new crystals are formed. Under no condition should the cooling be allowed to decrease the coefficient to 1.05 - 1.1, because with low supersaturation, crystallization progresses too slowly. Crystallization starts immediately after the fillmass is dropped from the pan, because it is surrounded with more or less supersaturated mother syrup; The crystallization does not cease until the supersaturation is decreased. It is of course essential that during the entire time of cooling, the temperature and concentration should be the same throughout all portions of the fillmass, which should be thoroughly stirred and kept in motion.

Crystallizers are generally used to work the fillmass. These are, as a rule, horizontal cylindrical containers with a double shell or other arrangement for warming and cooling; they are always provided with axial shafts fitted with radial mixer-arms. The fillmass can be conveyed from the vacuum pan by means of troughs when the pans are sufficiently elevated; otherwise, it must be pumped by means of air from the pan to the crystallizers, or else lifted by means of a vacuum.

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It is quite impracticable to convey fillmass through pumps because of the excessive cooling in the pipes and the formation of scums.

Crystallizers can be worked in one or two methods. One way is to cover the fillmass with a somewhat highly supersaturated mother syrup in order to bring the supersaturation coefficient up to about 1.13. Such a fillmass, with a water content of 67%, cannot be cooled immediately but must be maintained very near the temperature at which it is dropped, 75 to 80° C., for several hours. When the supersaturation becomes such that new crystals form, the temperature can be lowered and the crystals will increase in size. When the supersaturation coefficient is decreased to 1.1 - 1.2 by means of crystallization, the fillmass can be cooled off slowly. If after 18 to 24 hours the temperature drops to 60° C., enough diluted syrup must be added to make the mass plastic in order to centrifuge it. The work should be finished when the temperature falls to 55° C.

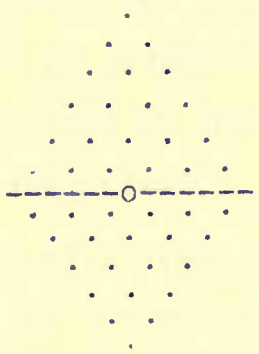
Since with stiffly boiled fillmasses, errors are apt to occur in the work, it is best to work only thin fillmasses in the crystallizers. It is obvious that the fillmass can be boiled so stiff that the mother syrup will have a saturation coefficient of 1.3. After dropping a pan, the steaming out water should be allowed to run to the fillmass in the crystallizers, or else hot diluted syrup should be added in order to decrease the supersaturation coefficient of the mother syrup to 1.15 - 1.2. A plastic fillmass like this has a water content of 8.0 - 8.5%, and can be more rapidly cooled off so that it can reach the centrifuging temperature, of 45 - 50° C., in 15 to 20 hours without formation of new crystals, and without any further dilution. Naturally, with this method of work, the same yield cannot be obtained as when working stiff undiluted fillmass. It is quite possible to get as low as 70% purity when the mass is boiled for a long time with green syrups

in the pan. The greatest care must be taken in this work; any neglect will cause great difficulty in centrifuging which cannot be obviated either by heating or dilution, and much sugar will be lost causing a correspondingly light yield.

An apparatus somewhat different from the crystallizer, though constructed on the same principle, is that of the so called "Kochmaischen". These are tight, enclosed crystallizers in which syrup is drawn into the cooking space very slowly under a vacuum, and is then boiled with the addition of some dilute syrup. This fillmass is finally cooled off in the same apparatus. The apparatus works at first as a vacuum pan with a small heating surface, later as a crystallizer. In this type of apparatus, crystallization of the sugar is brought about by slow evaporation and finally by cooling. Theoretically, evaporation should proceed at such a rate that the supersaturation of the mother syrup should be maintained at the desirable point of 1.2 - 1.3. If this were practical, this type of apparatus would yield the quickest crystallization and the very best results; practically, though, it fails on account of one's inability to properly regulate the correct supersaturation. New crystals are always apt to form, and these must be redissolved by the addition of a fresh amount of dilute syrup, whereby the entire equilibrium of crystallization is destroyed. Hence, this apparatus yields, in practice, no better or quicker desugarization than can be obtained with cooling in crystallizers.

No matter what method or means are used to work the fillmass, the crystallization can never be obtained as rapidly as with boiling, since the mother syrups have a lower and constantly decreasing purity. With normal methods of work, it is not advisable to carry the desugarization of the mother syrup of the first product too far, because of the necessity of too great a number of vacuum pans. As a rule, with

stirring apparatus, crystallizers or "Kochmaischens", a purity of the green syrups of 75 is satisfactory; a few factories work as low as 70 - 72, while a great number work over 75. This is of particular interest in obtaining good raw sugar which centrifuges pure white and is easily refinable, and it is rarely desirable to have a green syrup which has been too fully desugarized. The purity of the syrup depends, not so much on the method of work and time of crystallization, but on the size and amount of crystals obtained. The finer the crystals are, the more surface is present and the quicker the sugar will crystallize out. While one kilogram of raw sugar has practically a total crystal surface of three square meters, the same weight of very fine grained sugar has a total crystal surface of seven square meters; hence, if it is desirable to obtain rapid crystallization without other considerations in view, the mass should be worked with fine crystals. To obtain granular sugar with the usual amount of desugarization of the mother syrup, considerably more time and space are needed in the vacuum pans and crystallizers, than when working a fine grained product.



CHAPTER XVII.

C E N T R I F U G A L W O R K.

When the first product fillmass is boiled and worked correctly, there is no difficulty in separating the syrups from the crystals in the centrifugals, and the process is one of the simplest of the entire manufacture. The centrifugals used are of either the hanging or the fixed type. In Germany the latter are mostly used, though the former have many advantages. Formerly, the drums of the centrifugals had a diameter of approximately 800 mm., and a capacity of 80 to 100 kg of fillmass; at present larger machines are in vogue with a capacity of 150 to 500 kg of fillmass. These are provided with bottom dumps, which obviate considerable work. Attempts to install continuous centrifugals have heretofore been entirely unsuccessful.

For good centrifugal work, the perforations of the screens in the drums are of great importance. In order to avoid the screens from lying closely against the walls of the drum, which causes a large portion of the holes or slits to become unserviceable, the sieves should be laid on a coarse screen to give sufficient space between the two, and render all of the surface of the fine screen efficient. The holes in the screens should be as small as possible without making them of a size that they would become clogged by the crystals. The appropiate size must be determined by every factory. There is no particular advantage in having the holes or slits conical; when attempts are made to better the method of perforating the screens, the essential feature is the form and size of the holes and slits on the inner screens. Smooth screens punched out of plates are in general the most popular.

The fillmass is conducted to the centrifugals by means of troughs when the mixers and crystallizers are higher than the machines; when this is not the case, the fillmass is pumped by means of air or

CHAPTER XVII.

C E N T R I F U G A L W O R K.

properly constructed fillmass pumps into the sugar mixers and is then led through the proper channels into the centrifugals. Large buckets or wagons have the advantage of conveying the fillmass to the centrifugals warm and also distribute equal quantities of material, but the work is less cleanly than with the troughs or distributing necks provided with adjustable discs for stopping the flow. Even very stiff fillmasses flow satisfactorily through such openings, but it is essential to keep the fillmass in constant motion while it is in the mixers in order to prevent the sugar crystals from settling on the bottom. The mixers should also be provided with a double mantle for steam, though with first product fillmass, it is rarely necessary to use this installation; and material which centrifuges poorly must be warmed previously anyway. The filling of the machines from the mixers must be measured entirely by the eye. If the centrifugals are filled while standing idle, as is usually the case with first product goods, a mark inside of the drum can be used in order to obtain an equal charge at each filling. If the centrifugals are filled while running, as is often the case with after product fillmasses, the workmen readily acquire the faculty of judging the proper charge. When fillmass centrifuges easily, the syrup is usually separated from the crystals before the centrifugal reaches its normal speed. Naturally, the outside layers of the crystals contain less syrup than that portion directly in contact with the screen. The difference, however, is not very noticeable, and the sugar, after being packed and transported, becomes very satisfactorily mixed.

If fillmasses centrifuge poorly, the machines must be allowed to run considerable time at their full velocity, and even then one is apt to find numerous places which may be entirely uncentrifuged. It is very difficult to overcome such evils in centrifuging and it always

means considerable loss. The difficulty should be remedied early in the work. Poor centrifuging is usually caused by crystallinic powder, which is due to poorly conducted crystallization processes; however, the presence of foam and scums, or else a great cooling of the fillmass, will also cause poor work.

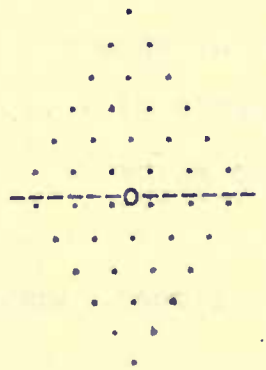
Fillmasses are apt to become scummy from the agitation in the crystallizers or mixers, when the arms lift out of the mass and then entrap air as they descend again; therefore, the stirring appliances should always be entirely covered with fillmass. Since, however, it is impossible to stop the stirring apparatus while emptying the crystallizer, on account of the crystals settling to the bottom, the machine should be kept running as slowly as possible to avoid the formation of scums. Generally 1/2 to 1, or at the highest 1-1/2 revolutions per minute are quite sufficient to keep the fillmass properly stirred, and also retain an evenly distributed temperature. The reason for scummy fillmasses yielding poor results in the centrifugals is very apparent, for the light foamy syrups adhere to the sugar and form a tough skin which cannot be removed by even the centrifugal force.

Care should be taken to avoid cooling of the fillmass below 45 to 50° C., for at a lower temperature the viscosity of the saturated and supersaturated syrups increases very rapidly; hence, any extreme cooling between crystallization and centrifuging is injurious and should be avoided. The viscosity of the syrup causes a waste of time more than poor work, particularly when the fillmasses are too cool. With warm fillmasses it does not effect the conditions, which are far more apt to be due to crystallinic powder. This latter separates in the mass similar to foamy syrup. The centrifugal force having little effect in separating it from the larger crystals. With poorly centrifuged fillmasses, a more or less satisfactorily centrifuged layer of

- 2 -

sugar lies on top, and there is then a tough layer of cemented crystallinic powder around which there is usually more or less syrup which fails to penetrate the fine layer of powder.

If such fillmasses are due to poor boiling or handling, there is nothing else to do but to redissolve the crystallinic powder in the crystallizers or mixers, and then rework or else redilute with syrup. If this method is used cautiously, there need be no fear of dissolving too great an amount of sugar from the larger crystals. With crystallizers, it is even possible to re-obtain the sugar by means of a second cooling. The ease of centrifuging fillmasses depends upon the degree of fineness of the small crystals. Every fillmass is apt to contain more or less crystallinic powder or fine crystals, of which anyone can be convinced by using a microscope. If a poor quality fillmass is not discovered until it reaches the centrifugals, there is no choice but to centrifuge with steam, which dissolves the fine crystals and allows the syrup to flow off after being heated. The steam is usually introduced between the drum and the outer shell in order to distribute it more fully and to allow it to work slower without dissolving too great a quantity of the large crystals. With all these methods, however, the yield in the centrifugals is usually decreased far more than by properly preventing the formation of the crystallinic powder in the mixers and crystallizers.



CHAPTER XVIII.

R A W S U G A R .

Raw sugar is obtained from the fillmass by simple centrifuging. The centrifugals are filled with as much first product fillmass as their construction will allow. The larger the machines, the more time can be saved, for it takes no longer to centrifuge a large mass than a small one, and just as much time is taken to charge and recharge small masses as larger ones. For this reason, centrifugals of large diameters and capacity are best, and when these are provided with bottom discharges, a large saving can be made in labor.

Raw sugar consists, like the fillmass, of crystals and adhering syrup, except that it has less syrup. The properties of the syrup and the sugar are practically the same, as in the fillmass, and the yield of raw sugar that can be obtained by either long or short periods of centrifuging, depends on the size of the crystals and the amount and purity of syrup adhering to them. From 100 parts of crystals in the fillmass, one obtains from 50 - 60 parts of syrup. About 8 - 12 parts of syrup adhere to the raw sugar. The average thickness of the layer of syrup, on raw sugar crystals of 92% purity, is about .01 - .015 mm., and on those of 88% purity, about .015 - .020 mm.

The question as to whether or not it is advantageous to make a raw sugar of high or low purity, depends on the price of different grades of sugars. As long as the price for one degree purity exceeds 1% of the price of low goods, it stands to reason, that it is best to make raw sugar. It is obvious that to obtain good white sugar, more centrifugals are essential than otherwise and there is a larger yield of molasses.

A satisfactory raw sugar, that is, one that is readily saleable, depends not alone on its purity but on its apparent properties, such as the sharpness, lustre, color and eveness of the grain; and the

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A satisfactory raw sugar, that is, one that is readily salable, depends not alone on its purity but on its apparent properties, such as the sharpness, lustre, color and evenness of the grain; and the

adhering syrup must not be too viscous, and must be as free as possible from small crystals. To be certain of the consumption of a sugar, it is best to have large crystals. It would be well if the valuation of raw sugar were based on all of its properties. At present there are no satisfactory commercial methods of handling raw sugar. The price has been based on the purity calculated from the ash content, while the yield of refined sugar depends, not only on the ash, but on the amount and properties of the organic nonsugars present. All propositions to change the methods of valuing sugar have been discouraged, because of the unreliability of the methods of research, and the uncertainty of results, so that all commercial tests are still based on the ash content.

The color of raw sugar is not always an indication of its composition. When a bright sugar is obtained, it is well to note if its color is natural or artificial. The color of the molasses is of as much importance as the color of the crystal. With dark sugars, the amounts of syrup are larger than with those that are brown, and the purity, too, is usually higher with light products. When the crystals are not a clean white, a light yellow color is not so bad for refining as gray, since the yellow color is more easily removed by boneblack and blueing, and the refined sugar is of better quality. The cause of gray color in a sugar is attributed to the presence of iron in the juice, following a poor saturation. Iron salts dissolve or remain dissolved when the juices are not sufficiently deffecated in the second saturation; the same condition ensues by over-carbonation. Either thin or thick juices, that are carbonated sour, are very apt to contain iron, and give considerable difficulty when attemps are made to refine the raw sugar from them. Gray sugars also result from the presence of hydrogen sulphide in the carbonation gasses, causing the formation of sulphide of iron which remains dissolved in the juice in small quantities.

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Good raw sugars do not deteriorate in storage, provided they show an alkaline reaction with phenol and are free from organic non-sugars and lime; the latter has an inverting action in syrups. Alkaline fillmasses derived from soundly alkaline juices, give stable sugars, that is when the syrups are sufficiently saturated and remain so when stored in cool dry places. Under such conditions it is impossible for moulds to develop or vegitate. But if in storage the syrups or the sugars absorb water and become diluted in any way, there is an immediate danger of inversion, and a subsequent decrease in the alkalinity and polarization. Sulphured juices should generally give a more stable sugar than those which remain unsulphured, because small amounts of sulphurous acid salts remain dissolved in the syrup and act as antiseptics.

The form and sharpness of the crystal depend on the quantity and quality of the nonsugars. Juices that are well limed give better and harder crystals than those juices that are superficially handled. With the same purity of juice, sugar derived from fresh beets has a better grain than when made from those that are siloed. Certain lime salts have a decidedly bad effect on the crystallization, particularly those which collect from the molasses, and are accumulated in the juices. Both raw and refined sugars derived from such sources show a more or less pointed or needlelike crystal.

Raw sugar from the centrifugals is a warm heterogeneous mass which on cooling has to be sifted and mixed before it can be placed in storage. It is better to use continuous conveyors instead of scrolls in carrying the sugar from the machines to the sifting screens, in order not to injure the sugar crystals. Either drum or shaker sieves are used for sifting the raw sugar. When the sugars are sticky and run as low as 88% purity, the sieves have to be provided with brushes

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or forked arms to brush the material through the screens. Since cool air decreases the stickiness of the crystals, it is often injected through the screens. Lumpy sugar should be mixed with syrup and run back to the centrifugals.

Sugar obtained from fillmasses that have been slowly cooked, and carefully worked in closed crystallizers and well centrifuged, do not need screening except to insure more thorough mixing. After sifting, the sugar is stored away in bags or in bulk. Sugar should never be stored while hot, particularly not in piles where it is apt to heat and invert rapidly. This phenomenon is probably due to the oxidation of certain organic nonsugars. The weight of the sugar can be easily estimated when stored in sacks; when stored lose the carrying wagons have to be weighed. It is almost impossible to estimate weights of sugar exactly from the capacity of storage piles, on account of the extreme variance in the specific gravity of the material. The sugar warehouse should be cool and dry, and care should be taken that the store-room is not overly warm nor subject to the warm damp atmosphere of the factory. Under the first conditions, the sugar dries and losses weight and is more difficult to refine, on account of increased viscosity of the syrup surrounding the crystals. In damp storage, the sugar absorbs water and becomes so damp that the syrup flows off of the crystals and becomes sufficiently dilute to support the growth of moulds, and suffers subsequent inversion. Other difficulties are the bursting of sacks and the occurence of large streaks of syrup. In cool storage, none of these conditions ensue, unless the sugar is below 88% in purity. At low temperatures, syrup adhering to the crystals acts like a protective skin.

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CHAPTER XIX.

THE PRODUCTION OF WHITE SUGAR

In the manufacture of beet sugar, it is often desirable to fully separate the syrups from the raw sugars in order to obtain a white sugar for the market. Such sugars when crystalline are designated as "granulated", when ground as "powdered" or when in masses "Piloe". These products are not refined sugars, but the raw products of the factory.

In the production of granulated sugars the fillmasses are centrifuged in a manner similar to that for the production of raw sugars, except that they are worked warmer in order to get rid of more syrup. The syrup that is not driven off by the centrifugal force, is washed off with water, steam or a saturated solution of sugar, in such a manner as to dissolve as little of the crystals as possible. To improve the color of the crystals, ultramarine is put into the vacuum pan or the wash waters. For this purpose, only the very best ultramarine should be used, as poor material changes its color and spoils the sugar. Only good juices can be used with advantage for the production of granulated sugar; when the thick juices are not of sufficient purity, they should be improved by the addition of yellow sugars. The production of a good even grain, and an easy working fillmass, is of far more importance in this work than in the production of raw sugar. For the working of granulated sugar, large centrifugals are used though they are not filled to the same extent as in raw sugar work, in order that the layer of sugar can be washed more evenly. When one used a saturated sugar solution, for the removal of the syrup from the crystals, less sugar dissolves. If in the production of white sugar, a portion of it has to be dissolved in the wash waters, and these in turn are remixed with the syrups, the final yield of granulated sugar is largely

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impaired. In beet sugar houses, pure sugar-wash-syrups are seldom used; water and steam are used together or separately. Naturally, it is important to use the water and steam so as to dissolve as little sugar as possible. Water is applied by sprinkling or by spraying with compressed air. When steam is used, it is thoroughly drained or else superheated before entering the centrifugals, the covers of which are put on before steaming so as to condense as little of the steam as possible. The so called Russian method of washing, consists of passing the steam between the outer and inner cylinders of the centrifugals. The steam acts as a heating agent, decreasing the viscosity of the syrups so that they are more readily thrown off. By this method less wash syrup is made. Care must be taken that the steam does not come in contact with the wash water; for this purpose, a special opening is made for the steam, so as to distribute it equally around the cylinder. Before the final washing with water or steam, the sugars have a preliminary washing with the last washings of the previous charge, or with a saturated thick juice. By this method, the green syrups are kept fro.. coming off too dilute, and so save steam in the subsequent boiling. Such methods of washing are complicated, and hence, it is doubtful if the slightly increased yield is worth the trouble of the extra work. This method should not be used unless the thick juice and wash syrups are very clear and pure. Since some sugar must, in all events, be dissolved from the crystals, one should seek a good yield and a careful separation of the syrups according to their purity, so that they can be reboiled with the thick juices into granulated sugar. The syrup which is first thrown off is designated as green syrup; that following is called green syrup tailings. The final product is a clear wash syrup which is either pumped directly back to the thick juice, or taken back into the pan.

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For the separation of the syrups, according to their purities, there are a number of methods in use, the simplest is that of separating them in the order in which they come from the machine. In consequence, it is best not to make the time of centrifuging too short, so that the syrups will have enough time to run off separately. Hence, the large slow running machines are best for the separation of the syrups. In some methods of separation, the syrups are caught in the cylinder of the machine, so that their separation is sharply defined and the work is accelerated considerably. One always needs more centrifugals for the production of granulated sugar than for raw sugar.

The further handling of the washed sugar, depends on the product desired for commerce. Crystalline and granulated sugars must be taken from the centrifugals moist and warm, so that the crystals will not stick together. When making "Pilée" sugar, the material is dried in the machines. When the sugar is steamed in the machines, it is seldom necessary to dry it afterwards, as it is warm enough to dry during the screening and transportation. When washed with water or syrup, the sugar has to be dried in granulators. If a sugar of even grain is sought, it must be passed through sorting screens. The material left on the screens is generally ground. It is very important to pack the granulated sugar in a cool dry place, otherwise a yellow coloring is apt to result. For the production of "Pilée" sugar, the centrifugals are provided with various appliances for the removal of the hard masses.

Another method of preparing white granulated sugar is to wash the fillmass. The finished material from the vacuum pan is cooled in the crystallizers from 40 - 50°C., and is then diluted so that the mother syrup is very weakly saturated. This method cannot be applied with fillmasses containing small fine crystals. The fillmasses are put

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into large four cornered, or oval tanks, the bottoms of which are covered with a fine screen. The syrups which filter through this screen are pumped away. The sugar is washed carefully and the syrups are drawn off separately. The first syrup that comes off has a purity of 70 - 75%; the second syrup serves as first washing for the new fillmass etc. Syrups are run to tanks in which water is added to bring them to the correct density for working. Since the temperature in the washroom varries considerably during the year, it is difficult to keep a constant density in the wash syrups. The temperature should not be allowed to fall below 20° C., for at low temperatures the syrups are exceedingly viscous, and the washing takes much longer. Saturated wash syrups are injurious; unsaturated, wash more quickly but dissolve the sugar and decrease the yield. It is only advantageous to use unsaturated wash syrups in the fillmasses which are highly saturated. It is best to work the fillmass so that the product from the crystallizers yield only a saturated mother syrup.

The yield of white sugar from this method of working is greater than from that of centrifuging, since a green syrup of higher purity is obtained; but the time consumed is very much greater. Another condition is the possibility of alteration in the material by long standing, such as loss of alkalinity and inversion. In consequence, the greatest cleanliness must be observed and a sound alkalinity must be established; for the latter, sodium carbonate and not lime must be used. If vigorous inversion once starts, all the material in the storage must be thrown out, and the floors, walls, and tanks must be thoroughly cleaned, and the work started anew. The method of tank washing is rarely used, except for refinery purposes.

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CHAPTER XX.

THE WORKING OF THE SYRUPS.

The object in working the syrups is to obtain, by means of crystallization, the recoverable sugar and to leave behind a mother liquor which is a true molasses. This end is obtained in various ways. The first operation is the concentration of the syrup; this is done in vacuum pans of the same construction as those used for thick juice. The circulation of the juice must be good, it must enter the bottom of the apparatus and the heating must be done with a low pressure of steam. The syrup is worked under three general principles:—

1. Blank boiling and subsequent crystallization in tanks, with or without the addition of crystals.
2. Blank boiling and working of the fillmass in crystallizers, in which the crystals are formed by cooling or by the addition of granulated sugar.
3. Boiling of the syrups to grain and further working of the fillmasses in crystallizers.

With any of these methods one can obtain a thorough crystallization of the sugar and a low purity of molasses, the differences lie mainly in the consumption of time. For the proper working of the syrup it should have the correct concentration and temperature during the period of crystallization. With pure syrups, an excessive saturation is apt to build too many fine crystals at one time, hindering crystallization, particularly so at low temperatures which causes an increased viscosity in the syrups. Too low a saturation on the other hand has a tendency to lengthen the time of crystallization, particularly with impure syrups. One can only work according to the rules of saturation when boiling to grain, or adding crystals. By other methods, the density of the syrup must be such that crystallization of the mother liquor is complete. A fully crystallized after-product-fillmass, should consist of sugar-crystals and a true molasses in a saturated, or better still, a weakly saturated condition.

CHAPTER XX.

THE WORKING OF THE SYRUPS.

The object in working the syrups is to obtain, by means of crystallization, the recoverable sugar and to leave behind a mother liquor which is a true molasses. This end is obtained in various ways. The first operation is the concentration of the syrup; this is done in vacuum pans of the same construction as those used for thick juice. The circulation of the juice must be good, it must enter the bottom of the apparatus and the boiling must be done with a low pressure of steam.

The syrup is worked under three general principles:—

1. Blank boiling and subsequent crystallization in tanks, with or without the addition of crystals.

2. Blank boiling and working of the fillmass in crystallizers, in which the crystals are formed by cooling or by addition of granulated sugar.

3. Boiling of the syrups to grain and further working of the fillmasses in crystallizers.

With any of these methods one can obtain a thorough crystallization of the sugar and a low purity of molasses, the differences lie mainly in the consumption of time. For the proper working of the syrup it should have the correct concentration and temperature during the period of crystallization. With pure syrups, an excessive saturation is apt to build too many fine crystals at one time, hindering crystallization, particularly so at low temperatures which causes an increased viscosity in the syrups. Too low a saturation on the other hand has a tendency to lengthen the time of crystallization, particularly with impure syrups. One can only work according to the rules of saturation when boiling to grain, or adding crystals. By other methods, the density of the syrup must be such that crystallization of the mother liquor is complete. A fully crystallized after-product-fillmass, should consist of sugar-crystals and a pure molasses in a saturated, or better still, a weakly saturated condition.

The saturation conditions of pure syrups are far more intricate than of pure juices. The saturation coefficients are derived from the solubility factors of pure and impure solutions, in consequence, the saturated conditions of the syrups depend on the quantity and quality of the organic nonsugars. The solubility of sugar depends on the influences of the salts as well. It appears though, that the nonsugars have less influences than the salts, providing the juices are properly handled in the carbonation and presses. The solubility of sugars and syrups of different factories are very much the same, depending on the purity. Syrups of the same purity have different saturation coefficients in special cases only. For example, under the influence of lime salts, Raffinose or other invert sugars in large quantities or when the syrups have a large salime coefficient. To prevent any misunderstanding, it is well to note that the solubility factors have nothing to do with the formation of molasses; they indicate merely the point to which the syrup should be boiled to make it crystallize. When sugar is more soluble in one solution than another, it is apparent that the first solution must be purer than molasses, even when highly concentrated in order to crystallize out the sugar, since a true molasses can be concentrated to the point of dryness without any sugar crystallizing. The action of the organic material on the solubility of the sugar varries considerably at different temperatures. If for example, a syrup of 62% purity is saturated at 20° C., (when one part of water will dissolve 1.05 times as much sugar as a pure solution at 20° C.) the same syrup is not saturated at 70°, until one part of water dissolves 1.5 parts of sugar.

The number, which at equal temperatures, gives the number of parts more sugar soluble in a saturated syrup than in a pure sugar solution, is called the saturation coefficient. The saturation coefficient is lower at lower temperatures for all syrups. For syrups of more than

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70% purity, the organic matter acts like sugar at low temperatures. The coefficient falls below 1.0, while at higher temperatures it is above 1.0. The influence of the temperature is proportionate to the impurity of the syrup; but little is known concerning the saturation coefficient of pure syrup at different temperatures. At best, research work could only give approximate figures. The saturation coefficients of syrups of different purities at the usual end temperatures of crystallization, (about 40 - 50°C.,) are of interest. At these temperatures the saturation coefficients of saturated syrups are:--------

Purity	75	Saturation Coefficient about	1.0
"	75 - 70	" " "	1.0 - 1.05
"	70 - 65	" " "	1.05- 1.10
"	65 - 60	" " "	1.10- 1.25
"below	60	" " "	1.3 -

The saturation conditions at different temperatures of a syrup of 60 - 62% purity are about as follows:--------

Temperature	1 Part of Water will Dissolve Parts Sugar In a saturated syrup of 60 - 62% purity.	In a pure saturated solution.	Saturation coefficient of the syrup.
80°	About 5.8	3.6	About 1.6
70°	4.8	3.2	1.5
60°	4.1	2.9	1.4
50°	3.4	2.6	1.3
35°	2.8	2.3	1.2
20°	2.3	2.0	1.15

From these figures it is possible to calculate the amount of water in the mother-liquor of the molasses for a proper crystallization when the purity is 60%. Such molasses can dissolve no more sugar since it is saturated, and it will offer no resistance to crystallization because its viscosity is as low as possible. In practice it is advisable to keep the molasses supersaturated, keeping the supersaturation coefficients between 1.05 and 1.10. The following figures give the composition of a molasses, showing the highest amounts of water possible for crystallization at various temperatures.

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Purity	Saturation coefficient about 1.0
" .75 - 70	" " 1.0 - 1.05
" 70 - 65	" " 1.05 - 1.10
" 65 - 60	" " " 1.10 - 1.25
"below 60	" " " 1.3 -

The saturation conditions at different temperatures of a syrup of 60 - 65% purity are about as follows:-------

Temperature	1 Part of Water will Dissolve Parts Sugar		
	In a saturated syrup of 60 - 65% purity.	In a pure saturated solution.	Saturation coefficient of the syrup.
80°C	About 5.8	3.8	About 1.8
70°C	4.8	3.2	1.5
60°C	4.1	2.9	1.4
50°C	3.4	2.6	1.3
35°C	2.8	2.3	1.2
20°C	2.3	2.0	1.15

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Composition of a Molasses of 60% Purity.

Temperature of crystallization	Sugar	Water	Organic Non-Sugar.
35° C.	49.4%	17.6 %	33.0 %
50° "	51.0 "	15.0 "	34.0 "
60° "	52.4 "	12.7 "	34.9 "
70° "	53.3 "	11.1 "	35.6 "

From these figures one can calculate the concentration to which the syrups should be boiled in order to obtain a saturated molasses. The molasses should be considered as having only sufficient sugar in it to give the proper purity. In order to boil a syrup to grain, it must be worked to supersaturation and all other conditions depend on this, as will be shown later. The figures for normal molasses would apply here only to obtain the correct concentration before centrifuging.

When the correct concentration of the syrup is attained, all the conditions for a proper crystallization are fulfilled. A high viscosity of the juice is a great hindrance to a rapid crystallization, since the resistance of the surrounding medium prevents the growth of the crystal. This condition cannot be improved very much by mechanically stirring the mass, since such means do not alter to any extent, the layer of syrup surrounding the crystals, and serve at best to give only an even temperature and concentration. One of the most important influences on the viscosity is the temperature. At temperatures of 75 - 90° C., or at the usual temperature of boiling, there is very little variation in the viscosity of pure or impure, saturated or unsaturated syrups. At lower temperatures, from 60 - 65° C., and below, the viscosity is very much greater in impure and supersaturated syrups than in pure and dilute material. At normal temperatures, the viscosity is sufficiently great to stop crystallization entirely. In other words, a syrup can be best saturated at a high temperature, and the period of crystallization can so be shortened. High temperatures can only be maintained by the use of pans or crystallizers. By the use of such apparatus, a faster crystallization is obtained than when using tanks.

Composition of a Molasses of 60% Purity.

Temperature of crystallization	Sugar	Water	Organic Non-Sugar.
85° C.	49.4%	17.6 %	33.0 %
50° "	51.0 "	15.0 "	34.0 "
60° "	52.4 "	12.7 "	34.9 "
70° "	53.3 "	11.1 "	35.6 "

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Further considerations for a good and quick crystallization of the syrups are eveness of temperature and concentration in all portions of the mass, and a sufficient quantity of available crystals on which to grain. These conditions can be accomplished only with vacuum apparatus or crystallizers. The finer the crystals in a given weight, the more rapid the crystallization will be. The minuteness of the grain has, though, definite limits, depending on the size at the end of the period of crystallization, which must be such as to carry on the centrifuging with as little difficulty and loss as possible. Of course the commercial purposes for which the sugar is destined is an important consideration in the choice of the crystal. When it is necessary to make a good large crystal, a large weight of fillmass has to be worked.

The crystallization of the molasses is the greatest source of trouble with which beet sugar houses have to deal. But when the work is done with sufficient care, a larger yield can be obtained without any considerable increase in the cost of working. The management of the work is becoming much easier on account of the use of apparatus for determining the concentration of the syrup during boiling. Formerly the concentration was determined only by the "string proof" method, which gave very unreliable results; in some factories the hot syrup is spindled, but such results are no better than the former; when the tests are made in the laboratory, the results are obtained too late to make any change in the concentration. The only satisfactory method is to use pan control apparatus with tables for the temperature correction for each syrup.

(a). Working of the Syrups in Tanks.

It is impossible to obtain a thorough crystallization of sugar by a single boiling of green syrup of 75% purity, since for this purpose the syrup would have to be concentrated too much. So as a rule,

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the syrups are boiled twice, when they are worked in tanks. The first boiling is light in order to obtain a good grain and a green syrup of 65 - 68% purity, which latter is reboiled to the proper concentration. For the first boiling of the syrup, no definite rules can be laid down, since the concentration depends on the size of the grain desired in the second product sugar, also on the size of the tanks and temperature in the tank room. As a rule, the syrups are boiled to about 13% water, and are then dropped into large low tanks. With very pure syrups, such as are obtained in granulated-sugar work, the fillmasses are often put into movable tanks. It is only a question of time when such crude methods will be entirely supplanted by boiling in pans or crystallizers; which accomplish in one operation, with much saving of time and energy, the same work that has to be done in two operations with tank crystallization. With the imperfect methods in vogue, one seldom obtains a mother syrup under 65% purity, which has to be reboiled into a third product fillmass and be recrystallized in tanks; but when the purity of the second product syrup is 3% higher than molasses, the material can be reboiled with advantage, for with each per cent decrease in purity, the yield from the fillmass is increased about 1.7%. The boiling of these impure syrups must be carried on by means of a vacuum-pan-control-apparatus, with the aid of the following table in order to figure on a molasses of 58% purity.

Real purity of the syrup	68	67	66	65	64	63	62	61	60
Percentage water in the fillmass.	11.5	11.8	12.2	12.5	12.8	13.2	13.5	13.8	14.1

These are the largest possible numbers showing the percentage water and the concentration of the syrup, in order to obtain a complete crystallization from the final fillmass. To provide against all contingency, it is best to concentrate 1/2 to 1% less moisture than the table shows. This is particularly advisable where the grain in the fillmass is small

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on account of the crystals falling to the bottom of the tank, leaving the upper layers without any crystals to build on. An established viscosity is essential and must be taken into account in determining the water content. On account of this, a stiffer fillmass must be worked for large tanks than for small ones. When the condensed water from steaming out the pans is not caught, but runs into the tanks, the syrups have to be still more concentrated. The temperature of the fillmasses at the beginning of the crystallization is that of the pan 80°- 90° C. In order to keep a fillmass from cooling too rapidly, the tanks are heated to 40°C., by means of steam or coke ovens. After about two months, the temperature is dropped to 30°C., and crystallization finished. The well formed crystals, (which vary considerably in size, because no boiler can contain an absolutely even grain) are found on the bottom of the tanks, while the syrup above is comparitively free from grain. The removal and centrifuging of the fillmass presents no difficulties when the fillmass is worked in crystallizers, it should be kept stirred at 40 - 45° C. Crystallization in tanks is unsatisfactory on account of the tendency of the crystals to sink to the bottom of tank, in consequence of which the upper layers of syrup have a higher purity than the lower layers in which the crystals settle. To overcome these difficulties, tanks have been fitted with various types of stirrers, or have been provided with pumps to keep the mass thoroughly mixed. The costs of such installations are high. Any improvements in the work should be in the installation of vacuum pans and crystallizers. A simpler and cheaper method of stirring is by means of compressed air, which is conveyed to the bottom of the tank by means of a pipe. This method can be applied with only comparitively thin fillmasses.

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(b) The Working of Syrups in Crystallizers.

In this method also, it is impossible to obtain a low molasses from green syrups in one operation; because the syrups would have to be concentrated too highly. For a thorough crystallization, the figures given in the table in the previous chapter can be utilized. With pure syrups which have to be highly concentrated, too many crystals are apt to form, spoiling the eveness of the grain. To prevent this, green syrups of 70% purity must be boiled thinner than the table shows, and in consequence, cannot be crystallized to the purity of a molasses. A final syrup of 63 - 65% purity is obtained, which has to be reboiled and recrystallized. For crystallization work, the syrups are boiled to about 10% water, and are then cooled in the crystallizers with the addition of 15 - 25% sugar. The sugar which is thrown in must be previously warmed with hot saturated syrup, so that fresh crystals will not form by sudden cooling. It is best to form the grain directly in the pan, after concentrating the syrup.

A cooling in the crystallizers must be carried on very slowly. The crystallizers must be provided with a double covering to keep the fillmass warm. The end-temperatures must not be allowed to sink below 40° C.

The stirring of the fillmass does not have to be active, and it is not essential that the mixer arms should revolve oftener than once every two minutes, but they must be kept constantly in motion. The time of crystallization depends on the grade of the sugar and syrup desired. To reduce a syrup of 75% purity to 65% purity requires from 2 to 3 days; from 70% to 65% purity, to 60% purity, requires from 5 to 6 days. Syrups below 70% purity rarely crystallize evenly and are difficult to work in the centrifugal. After prolonged crystallization,

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fillmasses rarely work well, and any cooling on the way to the centrifugal must be avoided. A fine grain is used when it is desirable to work first product fillmasses and crystallizers, but the crystals grow unevenly, large ones becoming flat, which is undesirable and makes difficult centrifuging.

(c) Boiling of the Syrups to Grain.

The conditions which gives a thorough crystallization in the crystallizers, can be obtained by boiling the syrups to grain in the pan. If the syrups are thoroughly saturated in the pan, sufficient sugar can be saturated out to make the molasses of 65 - 67% purity. The concentration of this impure syrup can be carried high enough in the crystallizer to obtain a very low final molasses. During the building of grain, the saturation coefficients must be the same as those in boiling the thick juice, except when the purity is as high as 68%. After the grain is built, the saturation coefficient is decreased by the addition of syrup. When the crystals obtain a good size, the coefficient is again increased in proportion of the size of the crystals and the purity of the mother liquor, at the end of boiling, is again lowered. In practice, it is impossible to use saturation coefficients data; one is compelled to rely on the tables of percentage water which is in pure syrups at different times. The boiler must be careful not to build his grain too long; in syrups of 75% purity, the grain forms in a few minutes after the point of concentration is reached. With impure syrups, it takes from 15 to 30 minutes or more before the grain sets. The time can be shortened by increasing the concentration, but such proceedure gives too many crystals and too fine a grained sugar. As soon as enough grain is formed, more syrup is taken into the pan, and the steam turned on again. The further crystallization is carried, the slower must be the boiling. A purity of 65% can be obtained in from

the slower must be the boiling. A purity of 85% can be obtained in from and the steam turned on again. The further crystallization is carried. As soon as enough grain is formed, more syrup is taken into the pan. much processme gives too many crystals and too fine a grained sugar. sets. The time can be shortened by increasing the concentration, but impure syrups. It takes from 15 to 30 minutes or more before the grain in a few minutes after the point of concentration is reached. With to build his grain too long; in syrups of 75% purity, the grain forms is in pure syrups at different times. The boiler must be careful not data; one is compelled to rely on the tables of percentage water which lowered. In practice, it is impossible to use saturation coefficients and the purity of the other liquor, at the end of boiling, is again coefficient is again increased in proportion of the size of the crystals by the addition of syrup. When the crystals obtain a good size, the 65°. After the grain is built, the saturation coefficient is decreased those in boiling the thick juice; except when the purity is as high as building of grain, the saturation coefficients must be the same as the crystallizer to obtain a very low final molasses. During the The concentration of this impure syrup can be carried high enough in sugar can be extracted out to make the molasses of 65 - 67% purity. pan. If the syrups are thoroughly saturated in the pan, sufficient crystallizers, can be obtained by boiling the syrups to grain in the

(c) Boiling of the syrups to Grain.

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24 to 36 hours, but to reach 60% purity, it takes from 60 to 72 hours. It is not practical to carry the purity below 65% in the vacuum pan. Further crystallization should be carried on in the crystallizers, in which the fillmass can lie for many days. The temperature should be decreased at the rate of 10° every 24 hours. With the decrease in temperature, supersaturation results, during which, sugar crystallizes out of the mass. Water is added to prevent the formation of fresh crystals in the crystallizers, which latter would be unrecoverable dust, and hinder the work in the centrifugals. By proper control of the fillmass and cooling at 35 - 40°C., in 4 or 5 days a sugar can be obtained with good grain and high purity, with a low purity molasses.

By boiling the syrup, mechanical losses of sugar, by foaming and entrainment, can occur more readily than when boiling thick juices, on account of the viscosity of the syrup and the ease with which it heats; but with care and sufficient storage in the pan, these losses can be prevented.

By prolonged boiling, losses by the destruction of sugar occur in all sugar solutions, but these are small when the syrups are soundly alkaline. Losses are smaller too in crystallizer than in tank work, because the syrups are subject to injurious temperatures for a shorter time. As long as the temperature does not exceed 90 - 100° C., there is no immediate danger of loss. Decomposition of sugar is active in neutral or sour syrups.

The handling of the second product sugars is precisely the same as that of the first. In some factories, the low product goods that are below 90% in purity and have a fine grain, are not placed on the market but are remelted in the thin juice. In such cases the fillmasses from the tanks are not centrifuged, but the syrup is drawn

fillmasses from the tanks are not centrifuged, but the syrup is drawn off the first crop sugar and have a fine grain, are not placed on the market but are remelted in the thin juice. In such cases the same as that of the first. In some factories, the low product goods that are below 90% in purity and have a fine grain, are not placed on

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Be- cause the syrups are subject to injurious temperatures for a shorter time. As long as the temperature does not exceed 30 - 100° C., there alkaline. Losses are smaller too in crystallizer than in tank work, in all sugar solutions, but those are small when the syrups are soundly

By prolonged boiling, losses by the destruction of sugar occur can be prevented.

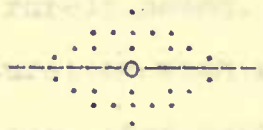
By boiling the syrup, mechanical losses of sugar, by foaming and entrainment, can occur more readily than when boiling thick juices, on account of the viscosity of the syrup and the ease with which it heats: but with care and sufficient storage in the pan, these losses

good grain and high purity, with a low purity molasses.

under the work in the centrifugals. By proper control of the fillmass and cooling at 35 - 40°C., in 4 or 5 days a sugar can be obtained with in the crystallizer, which latter would be unrecoverable dust, and of the mass. Water is added to prevent the formation of fresh crystals perature, supersaturation results, during which, sugar crystallizes out decreased at the rate of 10° every 24 hours. With the decrease in tem- which the fillmass can lie for many days. The temperature should be Further crystallization should be carried on in the crystallizer, in It is not practical to carry the purity below 85% in the vacuum pan.

24 to 36 hours, but to reach 60% purity, it takes from 60 to 72 hours.

off and the sugar dissolved directly in the tanks. Since the costs and the losses are increased with every boiling, it is necessary to carefully consider in every case, whether or not it is advantageous to rework the low sugars. Good second product sugars usually command a sufficiently large price, for them to be sold directly, unless, of course, the factory is in a position to make refined sugar. A good second product sugar should not have too fine a grained fillmass with viscous syrups, which on centrifuging are bound to give a sticky, low purity sugar. When such is the case, the molasses obtained from the centrifugals is allowed to run away. The wash syrups are diluted to 70 to 75 Brix and warmed to 50 to 70° C., in order to dissolve the adhering syrup. The entire operation can be done in a few minutes. dissolving very few crystals. The sugar thus obtained is of a high purity, dry and granular, and can easily be transported; and in addition to this, the molasses is low in purity.



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CHAPTER XXI.

METHODS OF PURIFYING THE GREEN SYRUPS.

Before boiling the green syrups they should undergo a purification. The simplest way to obtain this result is to pass them through the saturation. When the thick juice has an alkalinity of .02 -.04 and the first product fillmass an alkalinity of .05, the alkalinity of the first green syrup is not apt to be higher than .05 -.10. An alkalinity as low as .05 is not dangerous but essential when the syrups have to undergo a long period of crystallization in tanks. When crystallizers are used. the alkalinity is not apt to be decreased and the saturation is not essential, in fact it is best to omit it, because of the increased cost in diluting and reevaporating the syrups.

A filtration of the syrups before boiling is considered very advantageous, since following the centrifuging and boiling, the syrups contain more or less skum. The weight of this precipitate, which consists mainly of organic salts like oxalate or calcium and iron, is questionable, on account of the difficulty experienced in filtering the syrups, unless they are diluted or the material in the filters is porous. Although a raise is rarely noted, the physical properties are improved by filtration or saturation with sulphurous acid. It is generally acknowledged, in practice, that healthy syrups work very satisfactorily without either filtration or saturation. Another method of purifying the syrups, is to dilute and heat them with the addition of lime or baryte and then saturate them with carbonic or sulphurous acid. Since under these conditions, lime acts on the concentrated organic matter in much the same manner as it does in the thin juice; it is apparent that no noticeable results will be obtained unless the defecation of the thin juice was not carried on properly. An increase in the purity by the use of lime is not to be expected, but the syrup should

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A filtration of the syrups before boiling is considered very advantageous, since following the centrifuging and boiling, the syrups contain more or less mud. The weight of this precipitate, which consists mainly of organic salts like oxalate or calcium and iron, is questionable, on account of the difficulty experienced in filtering the syrups, unless they are diluted or the material in the filters is porous. Although a raise is rarely noted, the physical properties are improved by filtration or saturation with sulphurous acid. It is generally acknowledged, in practice, that healthy syrups work very satisfactorily without either filtration or saturation. Another method of purifying the syrups, is to dilute and heat them with the addition of lime or baryte and then saturate them with carbonic or sulphurous acid. Since under these conditions, lime acts on the concentrated organic matter in much the same manner as it does in the thin juice; it is apparent that no noticeable results will be obtained unless the defecation of the thin juice was not carried on properly. An increase in the purity by the use of lime is not to be expected, but the syrup should

boil and crystallize better. The increased cost of purification rarely warrants the operation.

When the diffusion juice is insufficiently limed, a very interesting phenomenon appears in the working of the syrups. This phenomena known as scum fermentation, shows itself immediately after putting a fillmass in the tanks or crystallizers. Small bubbles of gas form and rise slowly to the top, making the surface full of foam and scum. The volume of the entire mass is increased as the gas is developed, causing an overflow of the tanks. The development is strongest while the fillmass is hot, and on cooling decreases slowly, ceasing entirely at 60° C. The quantity of gas developed is very variable. As a rule there is only a layer of scum on the surface, though the gas sometimes occupies from 50 - 100% of the space of the fillmass. The gas consists almost entirely of carbon dioxide; the cause of the development of this gas is not due to a real fermentation, such as is caused by organic growth, since the greatest production of gas occurs over 80° C., at which temperature all organic life is killed or rendered inert, the cause is probably due to the decomposition of certain organic salts, such as waste products of invert sugars and other organic material of high molecular weight. These get into the juice from poor or frozen beets and are not removed on account of poor liming. The gathering of scum never occurs with healthy beets, but with those that are bad, or when the defecation is too short or too cold. When this organic material accumulates in the syrups and is kept at a high temperature for some time, it absorbs oxygen from the atmosphere and decomposes. One of the products of decomposition is carbonic acid. While the other products are not volatile, they are generally acid in character and destroy the alkalinity of the syrup and soon render it sour. When such syrups contain nitrites, which is very often the case,

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they yield, on souring, nitrous oxide as well as carbonic acid, giving a dark color to the fillmass, which colors even the sugar a dark brown. The formation of these scums, increases the more the material is boiled and shows itself sooner in the third products than in the second. The yield from such fillmasses is not materially affected but the sugar obtained is dark, of a fine grain, neutral or sour, contains invert sugar and is very unstable; and the molasses is neutral or sour and contains much invert sugar.

To prevent the formation of these scums, it is advisable to lime the diffusion and thin juices vigorously. The syrups should be boiled at a higher vacuum and a lower temperature, and with the addition of soda. If none of these methods avail, one of the afore mentioned methods of purification should be used.

There are many other methods of purifying syrups and juices in which, materials like baryte, hydrogen-sulphide, ozone or the electric current, are used to precipitate the organic matter. None of these methods have received practical application.

A favorite method of utilizing the first green syrups is to carry all or a portion of them back to the diffusion battery, the raw juice, the defecation or the thin juice. A larger yield of first product sugar is obtained in this method than when boiling the syrup with the fillmass. The result of returning the syrups into the juice has the effect of lowering the purity and consequently increasing the time of boiling. If 78% syrup is returned to juice of 92% purity, at the rate of 3% of the weight of the beets, the resulting juice will have a purity of only 90%. But as shown above, slow boiling increases the yield of first product sugar. A simpler method of increasing this yield is, instead of taking the syrup back into the juice, to add

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the syrup to the thick juice just before the end of the boiling in the pan. This practice is applicable only with juices of very high purity, since with low purity goods, one can obtain only a poor grain and a poor sugar. When the green syrups are added to the raw juice, a good purification in the saturation is rarely successful. No good explanation can be given for this, and it is difficult to see why the organic matter of the syrups should not be altered and precipitated by a second defecation, for they undergo a treatment precisely similar to that of the thin juice.

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CHAPTER XXII.

MOLASSES AND ITS VALUE.

By molasses, is meant in a practical sense, the end-product of sugar manufacture, from which no more sugar can be obtained by either concentration or crystallization. The theoretical explanation of this, is that the organic matter holds the sugar in solution at all temperatures, and concentrations. There is a probability too, that the inability of the sugar to crystallize is due to the great viscosity of the concentrated syrups. Viscosity is due to the supersaturation or decreased temperatures of the syrup. When these conditions are removed, a crystallization is obtained, but the syrup is not a true molasses. The lowest purity obtained in beet sugar molasses, is 54 - 55% (= 51 - 52% apparent purity). The average purity is 58 - 60%, most factories do not get below 60% and some not as low. It appears that molasses derived from high purity thick juices are higher than the normal, following an energetic defecation and the removal of all the organic lime salts which hinder the crystallization of the sugar. A molasses of 60% or less is usually obtained from the thick juices below 91 - 92%. Molasses as a rule have a lower purity at the beginning of the campaign than at the end. The properties of the organic matter play an important part in the formation of the molasses.

Most molasses of commerce are not really such; because of poor crystallization they still contain crystallizable sugar. The composition of molasses of 60% purity, as far as water and sugar contents are concerned, depends largely on the methods of crystallization and centrifuging. When the work is carried out properly, molasses should contain from 13 - 15% water, though such molasses are not on the market, since at ordinary temperatures they are too viscous to be pumped, or to be handled in tanks. In consequence, they must be diluted to 18 - 20%

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water, (a Brix corresponding to 81 - 83). After diluting and warming, the molasses can be handled readily with syrup pumps. Molasses to be stored at normal temperatures in barrels or tanks, cannot be handled with ordinary pumps when concentrated to 80 Brix; it is worked with either bucket or magma pumps. Molasses is transported in tanks or cistern wagons. Its value is based on the sugar content when used for feeding, the manufacture of alcohol, or other purposes which are not of interest here.

Many different methods have been employed to recover the sugar from the molasses. The methods based on the solubility of sugar in alcohol have been extremely expensive and have been discarded as the price of sugar has decreased. The strontia method of recovery has not been practical, except in refinery work. The beet sugar industry utilizes only the Osmose and precipitation methods of recovery.

The Osmose process is based on the different osmotic pressures of the various constituents of the molasses. Since the organic matter and the sugars are diffusible substances, the Osmose acts on the molasses, only in the form of a high purity syrup and in the so called Osmose water, which is a sugar solution of lower purity than the molasses. The results of the Osmose are very unreliable with the true molasses of very low purities and vary according to the properties of the organic matter. Since the salts of the alkalies diffuse most readily, syrups with high saline coefficients are improved the most by Osmose. Therefore the results are very variable from year to year. Many syrups do not give good results with single osmosing, while others with two successive operations are much improved. Naturally, the second operation does not yield as good results as the first, since most of the diffusible salts are removed in the first osmosing. In general, on account of its restricted action, the Osmose cannot be used with advantage except

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in places where the concentrated Osmose water can be sold to the distilleries. In Germany the simplest kind of Osmose apparatus is used, in Austria many improvements have been made. These consist in using as much as possible of the paper surface, in having channels that do not stop up, in having the correct proportion of syrup in the water, in having the syrup and water spread out as much as possible, and in having as great a difference in density as possible between the layers, in having permanently high temperatures, and a continuous discharge. Much importance is attached to the properties of the Osmose paper. The purified syrup from the Osmose is boiled and crystallized at high temperatures. The sugar obtained has but little ash, but is rich in organic matter, and in consequence, has little value in commerce. The final molasses is almost worthless and cannot be used in the sugar recovery processes because it gives a poor product and lacks the salts, which in the strontia and distillery processes play an important part.

The precipitation processes are the best for the recovery of sugar, from beet sugar molasses, because of their simplicity, slight costs, small losses, pure juices and the cyclic manner in which they enter into the production of beet sugar.

The lime used in process must be pure and comparitively free from magnesia. Freshly burned lime is more active than that which has been stored. The greatest importance is attached to the pulverising and sifting of the lime in burr, hammer or ball mills. It is best to use a soft lime that mills easily, and to sift it through a 110 - 120 mesh screen, for the finer the lime the less is needed.

The operations of the process are as follows:-------

The molasses is diluted to 14 Brix and cooled to the temperature of the cooling water. A thorough agitation is essential in order to cool the mixture as rapidly as possible and to insure a thorough mixing

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of the lime. The quicker this occurs and the finer the lime is powdered, the quicker the lime will unite with the sugar to form insoluble saccharate. Particles of lime which ball together, unite with the water to form a hydrate, or dissolve and become inactive. The more the lime becomes inactive in this method, the more heat is developed and the more time is consumed in cooling and mixing, and more lime is dissolved in attempting to overcome these conditions. All the work should be done as quickly as possible in the cooler as well as in the presses, in order to prevent the decomposition of the saccharate. In order to prevent the lime from balling, it is best to add it in small quantities, preferably in the form of a dust, over the liquid, or to inject it by means of air. A decrease in the amount of lime can be obtained by such methods.

In general 80 - 120 parts of lime are used to 100 parts of sugar, from 2 to 3 times the theoretical parts of lime for the formation of trisaccharate, and more when the water is warm. The melted lime depends too, on the distribution and on the amount of sugar left in the waste water. The composition of the precipitated saccharate is not known, but in all cases, trisaccharate is dissolved into its constituents on boiling.

The saccharate formed in the cooler should be separated, from the mixing, in filter presses with as little pressure as possible. It ought to obtain a cake that will wash readily. The washing is done in the same way as the sweetening off of the first presses, and care must be taken to change filter cloths as soon as they begin to get hard. The wash water must be kept as cool and the quantity kept as small as possible, in order to decrease the loss of sugar and to have no more than is necessary to dilute the molasses.

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No attempts to work the concentrated molasses or to obtain lime salts by steaming. have been successful. The results being impure, poorly washable saccharates, or a poor yield. Frequent attempts have been made to recover a portion of the sugar in the waste waters by heating and calcining, but in general, the solution which has a volume of 800 to 1000%, the volume of molasses is usually allowed to run away or is used as fertillizer. The saccharate is taken from the presses to a mixer where it is diluted with thin juice. The saccharate decomposes immediately into hydrate of lime and monosaccharate. The defecation in this manner works very energetically and there need be no fear of any of the difficultly soluble trisaccharate remaining in solution with temperatures over 70° C. The latter compound is decomposed by carbonic acid very slowly, and so increases the sugar content of the lime cake. This action sometimes occurs when cold mushy saccharate is added to hot raw juice. Beet sugar factories which work only their old molasses, add to the raw juices from 2 to 2 1/2% of lime in the form of saccharate. When bought molasses is worked. too large an amount of lime is apt to be added to the saturation, and it is best in such cases to mix the excess saccharate with an abundance of thin juice and to filter off the hydrate of lime which precipitates out. After sweetening off the cake, this hydrate can be returned to the dilute molasses in which a monosaccharate forms, thus saving some lime.

It is impractical to attempt a precipitation recovery process independently of beet sugar manufacture, on account of the instability of the saccharate, and also beets, it is comparitively inexpensive in raw sugar work, since the saccharate contains the lime which would in all events have to be added for defecation.

The juices derived from the saccharate cake generally have a purity of 90 - 94%. They are never less than the purity of the beet

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juice, but are somewhat less crystallizable than the same. Therefore the yield of first product sugar is the same, if not higher, than when the saccharate is omitted. The reason for the decreased crystallization of saccharate juices, appears to be in the fact that certain lime salts do not separate in the precipitation of the saccharate, but remain with it and so get back into the raw juice. These compounds accumulate in the same manner as Raffinose, which is precipitated with the sugar. Factories which use the precipitation process have their crystallization impaired from year to year, on account of this action and it is very important that the final molasses of the house should be entirely discarded every 2 or 3 years. When these conditions are fulfilled, the yield of first product sugar is not decreased, the quality of the sugar is good and offers little difficulty for refining.

The use of molasses in feeding. The feed value of molasses depends on the amount of sugar it contains, and on the preserving qualities of the salts. It acts not only as easily digestible nourishment, but as a palateable appetizer, serving at the same time to preserve and stimulate the absorption of food, which under other conditions would be discarded. The great viscosity of the molasses in the cold is a drawback to its uses as food material, particularly so, in the agricultural districts, where there are no ready or simple means of warming and diluting the molasses. In consequence, the molasses are mixed with bran or ground meal, which absorbs the sticky material. This mixture makes a more or less dry granular mass and is easily handled. The sugar factories do the mixing in machines, using molasses at a temperature of 80° C. The temperature should not exceed the above limit, for in cooling in piles, it is apt to overheat, and in mixtures of malt or similar grain, the material not only browns, but sours. The

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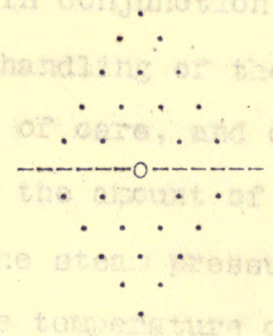
finished mixture must be cooled in low piles before it is sacked, or stored in large heaps. It is best to feed the stuff immediately after mixing, since it readily undergoes changes and decomposes in storage. When molasses feed is once wet, it not only spoils easily, but is also injurious to the cattle. The mixing and heating must be done in tanks with closed coils, with molasses of 80 Brix. When the feed is mixed with molasses of 78 Brix, it is unstable and runs together in summer.



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CHAPTER XXIII.

BOILER HOUSE WORK.

This is not the place to discuss the economy and technique of the boiler house, and the fire room. We shall only point out the conditions governing the relationship between the boiler house and the sugar factory. The proper burning of coal can be accomplished only with a good system of boilers, proper grates, and correct conditions of firing. Good firemen are always difficult to get for the short work of the beet sugar houses, and in consequence many automatic stokers are being installed, particularly those which allow the use of a poor quality of combustible. In conjunction with this, installations are being made for mechanical handling of the coal. The supervision must be done with the greatest of care, and careful data must be taken of the weight of combustibles, the amount of water evaporated, and the quality of the flue gasses. The steam pressure should be noted on recording gauges as well as the temperature of the feed water and the flue gases, and a record should be kept of even the draft under the boiler and in the chimney.

It is very advantageous to use a hot feed water. For this purpose the condensed water from the evaporators is well adapted. The temperature of this water depends on the pressure under which the steam is condensed. The hottest water comes from the first body with a temperature of 110 - 120° C. Some factories collect the water in closed traps and pump it directly back to the boilers. The temperature of the condensed vapors from the other three bodies, being of lower temperature, are collected separately and heated with the rest of the feed water to nearly 100° C. For injecting the hot water, it is essential to provide for ventilation of the suction line.

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as it acts like an alkali. Sugar can injure the boilers in one of two ways, chemically or mechanically. The method of injury depends on the quantity of sugar that gets into the boiler. If only a small amount of sugar gets in, the sugar is rapidly destroyed at the temperature of the steam, undergoing various changes of souring without the formation of any great amount of decomposition products. When large quantities of sugar get into the boilers, the sugar chars on the hottest portions of the metal and forms a porous layer of carbon. This increases rapidly, in thickness, until the metal underneath gets red hot and the pressure of the boiler bursts it. This action sometimes results in layers of several millimeters in thickness. This kind of injury is always the most dangerous and can wreck a whole boiler house in a few hours after the introduction of the sugar. There is no method of remedying the evil except by shutting down the entire plant, blowing off the water and refilling the boilers. In such case one should never fail to consider the importance of shutting down immediately and temporarily. Any other action would not be warranted, for it would be taking chances on wrecking the entire campaign and the boiler plant as well. The higher the pressure of the steam in the boilers, the more rapid is the decomposition of the sugar, and the more care must be taken with the plant. If when injury occurs, the blistering is not extreme and the metal of the boiler is good, the bulges can be pressed back and the work continued. One should consider, in all cases, the cheapest way of getting out of any such difficulties, and adopt any means rather than a complete change of the metal in the boilers.

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The other method of injury to the boilers, by chemical means, depends on the corrosion of the metal by the decomposition of the sugar into acids. The process and extent of corrosion depends on the amount of sugar in the boiler, on the steam pressure, the temperature, and the duration of the action. The higher the temperature of the water, the quicker the sugar is changed to acids. In most boilers used for heating purposes only, in which the pressure rarely exceeds 2 atmospheres, the sugar is destroyed very slowly. At 6 atmospheres (164°C.) the action is very rapid and the acids formed, attack the iron vigorously, causing general and severe corrosion. The small amounts of sugar that get into the boiler in the usual run of the work, cannot be prevented. To prevent any injury from them, soda should be added and the alkalinity should be maintained in all of the boilers. Too high an alkalinity is not permissible on account of foaming; the alkalinity should be such that 10 ccm., 1/10 normal acid neutralize 100 ccm., of boiler water. (Indicator -- Rosolic-acid). If the alkalinity decreases rapidly, it is an indication of the presence of sugar, and even the quantity can be determined, since .0114 g. sugar will neutralize 1 ccm., of 1/10 normal potash solution, or 2 kg., of sugar will neutralize 1 kg., of sodium carbonate. It is important to examine the water in each boiler, for one is apt to contain more sugar than another. The presence of sugar is shown by the odor of the steam, and is sometimes noticeable in the color of the water and by the presence of scums. A dark color is not harmful providing the water is alkaline. A layer of scale is a definite protection against the action of sugar, but this protection is not reliable since the scale is liable to crack off.

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To prevent injury to the boilers from sugar, the following recommendations can be made:------

(1). The separation of the vapors from the evaporators, and examination for sugar before they are added to the feed water, particularly after any loss of vacuum.

(2). Maintaining a definite alkalinity in the boiler house, by the addition of soda to the feed water, and regular investigation of the alkalinity of each boiler.

(3). Cutting out of service immediately, any boiler which shows any of the conditions of (2), or when the water becomes dark or carries a scum.

(4). Immediate investigation of the boiler, the moment the odor or dark color occurs in the water.

(5). Injecting a scale forming water at the beginning of the campaign in order to form a light layer of scale.

(6). The evaporator waters are not to be used at the beginning of the campaign until they become clear and uncolored.

The vapors condensed from the engines contain lubrication oil, the vegetable or animal fats of which are changed in the hot boiler water to free fatty acids, which attack the iron, in consequence, these oils must be carefully avoided. With this end in view, only pure mineral oils should be used, as these consist only of hydro-carbons and do not yield acids. But even these oils are injurious, in large quantities, because they are apt to smear, and coming in contact with the hot surface of the boiler tubes, they prevent the transfer of heat and cause a subsequent overheating of the tubes.

To prevent any possible injury from oils, separators should be used to remove the oil from the condensed steam. Filters to serve the same purpose are not very successful. The cylinders should be oiled with as little material as practical, in order to carry little oil into the condensed water. The layer of oil in the scum, besides

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its corrosive action on the boilers is very apt to stop up the valves and water gauges. To prevent this difficulty, a bent piece of metal is inserted in the drum, in order to bring the water to rest, and afford an opportunity to remove the oil. In most boiler houses, the high pressure boilers with pressure of 6 to 8 atmospheres, are placed directly next to the low pressure boilers, carrying from 2 to 3 atmospheres. When it is essential to alter the boiler house, the high pressure boilers should be used instead of the low pressure boilers, and the high pressure only, should be installed new. With the same quantity of coal, about the same amount of steam is made under 6 atmospheres as under 3, for the difference in the temperature between the flue gasses and the contents of the boiler are only about 20° C. The transfer of heat is not much greater because the transmission coefficient increases at higher temperatures. The loss of heat in the flue gasses differ very little in either case. When steam is reduced from 6 atmospheres to 2 or 3, there is very little heat lost, on account of the superheating of the steam. There are no advantages to be obtained in dividing the boilers into two systems, and only the difficulties of increased care and trouble, due to two steam lines. A battery of boilers under one pressure can be fired more evenly and economically than when under two pressures. When the irregularities in the steam consumption, are divided over a series of boilers, the firing does not have to be so heavy, nor does it have to be decreased to the same point as when using low pressure systems. In high pressure systems, the piping should all be covered in order to prevent the great losses of radiation. Great care must be taken of the boilers after the campaign, since they are used only 2 or 3 months every year and are cold the rest of the time, all precautions must be taken to prevent rusting during the period of inactivity. The best way to prevent any deterior-

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CHAPTER XXIV.

THE LIME-KILN WORK

Of all the different kinds of lime kilns used in sugar factories, the best are those which are charged with stone and coke at the top, and are heated without any preliminary furnaces or generator fires. The smallest amount of fuel is used in the Belgian kilns, but these are only successful with good cokes of low ash. Generator kilns can be operated with cheap fuel, and the cost of running them is as low as that of the Belgian kilns. A properly constructed kiln must yield a well burned lime and a saturation gas rich in carbonic acid.

The choice of the lime stone is of the greatest importance, but cannot be based entirely on the chemical analyses, for this shows nothing as to whether the stone will burn easily or hard or whether the foreign substances will have an injurious effect. The stone should be chosen for its visible properties, such as its structure, and the action of the foreign matter should be judged from the quantity and distribution in the stone. A large amount of impurities are, of course, an indication of a poor stone, and are injurious to the juices. A good test of the quality of the burnt stone is shown by its solubility in a 6% solution of hydrochloric acid. Aluminum, iron and manganese alone are not injurious to the lime, but iron in combination with either of the above, causes the stone to burn poorly. The presence of sulphur in either the stone of the fuel is apt to make a poorly soluble lime, on account of the sulphur forming sulphates. Alkalies in even small quantities form injurious compounds. The composition and the action of the impurities depends on the quantity and on the duration and temperature of burning.

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The burning of the stone to lime is a dissociation of the carbonate of lime into calcium oxide and carbonic acid gas and depends on

the temperature and the pressure of the gas. At about 800° C., the decomposition is only slight, but becomes more active at 900°. At temperatures below the point of decomposition, or at a dull red heat, the burnt lime reabsorbs carbon dioxide with energy, though at ordinary temperatures, there is no absorption of dry carbon dioxide. This is the reason for a rapid withdrawal of the gas from the kiln. For the practical work in the kiln, the stone should be heated to 1000° C., in order to thoroughly burn. The highest average temperature should not exceed 1200 to 1300° C. which is quite sufficient to thoroughly burn even large pieces of stone in a short while. Higher temperatures are to be avoided on account of the danger of overburning. Even a pure stone heated to 1600° C., for 5 or 6 hours, will remain standing in water for days without dissolving. If acid impurities are contained in the rock, the same action will occur at lower temperatures in a shorter time.

The size of the kiln depends, of course, on the amount of lime to be produced in 24 hours. Where the lime can be bought cheaper than by burning at the factory, the kiln should be no larger than to produce just enough gas for the saturation. To burn 100 parts of stone it takes 10 to 12 parts of coke, in consequence, about half of the gas is developed from the coke, the other half from the stone. If 2/3 of the gas developed is utilized in the saturation, it stands to reason that 1/3 more lime can be carbonated than is produced in the kilns. The size of the kilns depends, too, on the capacity of the gas pump. The more the gas is drawn from the kiln, the more intense will be the heat, and the higher the strata of maximum temperature. The more actively a kiln is worked, the easier it can be operated, less fuel being required to produce a larger amount of lime and gas. The zone of highest temperature will be larger when the kiln is of small diameter. The

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actual height of the kiln should not be less than 10m., and it should be the distance of its own diameter above the ground. The fire zone must lie so that the hot gases are thoroughly cooled by the upper layers of stone, before going to the pumps. With the Belgian kilns, great care must be taken to prevent the fire zone from going too high or too low. Beneath the fire zone there must be sufficient space for the lime to cool off, so that it can be drawn cold. The bottom of the kiln should be well walled and the draw holes should be tightly shut with doors, in order to prevent drafts from affecting the fire.

Breaking the stone in small pieces is advantageous, but not at all essential, and should be omitted where the working expenses are high. Chips of stone, dust and dirt, should never be thrown into the kiln, for with kilns of small diameter, they clog the draft and even block the entire kiln. The coke should be well broken, in order to insure a more complete burning before it reaches the cooling zone.

The burnt lime must not be drawn too seldom, preferable every 4 hours, in order to keep the contents of the kiln in motion, and to prevent the lime from remaining in the fire zone too long. Several trials have been made to obtain a continuous draw, in the kilns, by mechanical means, such as are used in the bone-black ovens. The hanging up of the contents in the kilns, is most often due to the fusing of the mass to the walls, the stone arches over these places and must be knocked down by means of long poles, which are inserted through the draw holes. With small kilns, the stone meshes so tightly together that it takes many hours to get it down. Immediately after drawing the lime, the kiln must be refilled. The refilling must be done as rapidly as possible, in order to prevent the dilution of the gas. The stone and coke must be evenly distributed when filling.

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The gas drawn from the kiln contains the gases of combustion, carbon dioxide from the stone and more or less ash from the fuel. The temperature varies with the quantity of gas and the height of the fire zone. An excess of gas should be avoided, in order not to get too high a temperature. For use in the carbonation, the gases must be cooled and freed from injurious constituents. For this purpose, a mechanical washing is sufficient, since small quantities of oxygen, carbon monoxide, and sulphurous acid do not do much harm and need not be separated. Too small an amount of air in the kiln, is apt to evolve an unduly large amount of sulphur dioxide, which is injurious to the juice. This difficulty can be obviated by not reducing the fire zone too much, and by avoiding the heaping of the coke in piles. The gas washers have only to cool the gas and to remove ash and products of distillation. They are cylindrical tanks of iron, wood or brick. When only a small amount of water is used, the iron in the washers is rapidly attacked, so wood and brick are often considered better. Most washers are based on the counter-current principle, in which the descending water comes in contact with the upflowing gas, the current of which is broken by baffle plates or layers of coke. In the bottom of the washer, a layer of 400 mm. of water is kept, through which the gas is passed. But since considerable carbon-dioxide is absorbed by the water, as little as possible should be used. The water is regulated so that it flows from the washer, both hot and dirty. The gas is less soluble in hot than in cold water. The gases should be well cooled in the upper portion of the washer, in contact with the cold water. The gas pump will work better and will have a larger capacity with cold gas, if for no other reason than because of the decreased volume of the gases.

In order to make the operation of the gas pump as easy as possible, the suction pipes should be large, in order to prevent loss of

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suction, and the water pressure in the washer should be as light as possible. The draft in the suction pipe should not be more than 1 m., of water. To regulate this pressure, the washer and pumps are provided with upright glass tubes, with the end under water. These tubes show the pressure at the different points, and the loss in pressure between the vasher and the pumps. The water in the gauge glass between the pump and the washer, should not show any great variation in pressure. It is not advisable to allow any of the water which is drawn from the washer, to get into the pump, all of it should be removed in a separator or trap.

The gas is proportionately rich in carbon dioxide, as the fuel and excess of air is decreased. In a kiln which uses 10% of coke, a gas can be developed with 37% of carbon-dioxide by volume, while with 12% of coke, under the same conditions, a gas of only 35% carbon-dioxide develops. Many kilns run as high as 30 to 35% carbon-dioxide, but this decreases rapidly after filling, and only runs high intermittently. A percentage of 25 to 30 is considered satisfactory and is what is usually obtained from generator firing. It is generally stated that a gas that is too rich in carbon-dioxide, carbonates more slowly than one of 25 to 30%. Though it is considered wise to thoroughly probe kiln problems, it is really best to run them with as little alteration as possible. Too great an excess of carbon-dioxide can be remedied by providing ventilation on the suction pipe.

S U P P L E M E N T

The sulphurous acid which is used after carbon dioxide, to saturate the thin juice, is prepared by burning sulphur in properly constructed stoves, or is else used in the fluid form in iron containers.

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The gas is proportionately rich in carbon dioxide, as the fuel and excess of air is decreased. In a kiln which uses 10% of coke, a gas can be developed with 37% of carbon-dioxide by volume, while with 15% of coke, under the same conditions, a gas of only 35% carbon-dioxide develops. Many kilns run as high as 30 to 35% carbon-dioxide, but this decreases rapidly after filling, and only runs high intermittently. A percentage of 25 to 30 is considered satisfactory and is what is usually obtained from generator firing. It is generally stated that a gas that is too rich in carbon-dioxide, carbonates more slowly than one of 25 to 30%. Though it is considered wise to thoroughly probe kilns possible. Too great an excess of carbon-dioxide can be remedied by providing ventilation on the suction pipe.

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Fluid sulphurous acid is somewhat more expensive than that obtained by burning, but it has many advantages, particularly where small amounts are used, and it is desirable to regulate the exact amount of gas. The gas is evolved from the container by passing a stream of cold water over it; this supplies a sufficient heat to boil a liquid acid. The liquid keeps the same temperature and about the same pressure,(approximately 3 atmospheres, at 15 - 20°C). The amount of acid entering the juice can then be easily regulated. In order to prevent any juice from getting back into the container, when it is empty and the pressure is low, a check valve is inserted on the Pressure line.

The acid developed in the burning of sulphur is apt to vary considerable with the grade and quality of the compound used in the stove and must be carefully watched before going to the saturation. The sulphur stoves must be so placed that they cannot be molested by workmen, and so that leaks will not be too annoying. Care must be taken that the sulphur does not sublime on the pipes over the stoves, or into the juice which it would seriously injure.

Liquid sulphurous acid is somewhat more expensive than that obtained by burning, but it has many advantages, particularly where small amounts are used, and it is desirable to regulate the exact amount of gas. The gas is evolved from the container by passing a stream of cold water over it; this supplies a sufficient heat to boil a liquid acid. The liquid keeps the same temperature and about the same pressure, (approximately 3 atmospheres, at 15 - 20°C). The amount of acid entering the juice can then be easily regulated. In order to prevent any juice from getting back into the container, when it is empty and the pressure is low, a check valve is inserted on the pressure line.

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CHAPTER XXV.

HEAT LOSSES DURING THE WORK.

With the great variations and difficulties of a sugar factory, it is almost impossible to obtain a correct balance of the heat conditions. It is of the greatest importance to utilize as much of the heat in the steam from the boilers as possible, for a sugar factory utilizes more of its steam for heating purposes than for power. For mechanical work, only 1 to 2 percent of the heat in the steam is utilized. After this small amount is utilized, the rest of it must be turned to good account in heating, to make use of all the heat in the fuel. In all the operations in the factory, in which steam is used, such as evaporation, boiling, and reheating, no heat is really lost and in most instances is available for further work.

The heat losses can be divided into three classes.

1. Heat losses in the boiler house.
2. Heat losses in the steam by condensation in the pipes.
3. General losses.

The heat balance can be determined with certainty in regard to the 1st., and 2nd., conditions only.

Heat losses in the boiler house. With good and properly constructed apparatus, only from 60 to 75% of the calorific value of the fuel is obtained in the steam, the rest of the heat is lost in the flue gasses, and through radiation. These losses can be readily and accurately determined.

Heat losses in the steam. The steam developed in the boilers is utilized in the cylinders of the engines, and for heating purposes, in this way there are two means of loss of heat,-- radiation, and condensation, both through the walls of the pipes and cylinders, and in the work done in the engines.

The amount of heat lost in the pipes depends on many conditions, principally the length of the pipe, the quality of the insulation, and the temperature differences between the steam and air. To decrease these losses, the piping should be as short as possible and should be covered with good insulating material. The steam should be superheated, because superheated steam, on account of the greater differences in temperatures, loses less heat on the walls of the piping than wet steam. Superheated steam remains stable as long as it is overheated, just as hot air, and is like it, a poor medium for the transfer of heat.

The cylinders of the engines which cannot be well insulated, are the source of a greater loss of heat than well covered pipes, and the whirling movement of the steam in the cylinder, is the cause of extra loss. The amount of heat used in the mechanical work, can be readily calculated, on the bases of the mechanical equivalent of heat, which is 424 mkg., which is equivalent to 1 calorie. 1 H.P. in the steam cylinders is figured at 11.80 kg., of condensed steam per hour. The steam performs mechanical work by expansion and pressure on the piston. There are no heat losses directly due to this work, for the heat energy necessary to accomplish work in one place, is immediately taken up in another. The entire amount of heat taken into the cylinder can be wholly accounted for in the amount lost in cooling, that utilized in mechanical work and in the remaining heat of the exhaust steam. Experiments have shown that in factories with a great number of engines and long steam piping, only 15% of the heat in the steam is utilized in the machinery. 3 1/2 % of this is used in the performance of mechanical motion, 2% is lost in the cylinder by cooling and the remaining 10% is lost through condensation, both directly and in the exhaust steam. The amount of steam lost in transmission from the boiler to the engine in short distances is probably not more than 5%. Assuming that 1/2 of

the steam is utilized in the engines at full pressure, and the other 1/2 goes directly to the apparatus, the heat losses on the way are about 10% of the total heat taken up in the boiler. Many attempts have been made to decrease these losses, but no means have been yet attained which yield pecuniary gains.

The old full pressure engines are being replaced with modern expansion engines. It is clear though that such installations do not materially decrease the heat losses in the development of the power, and the same amount of heat must be utilized to do the actual work, hence, only the radiation losses can be decreased. This can only be done by shortening and simplifying the piping and replacing the small machines with large ones. Whether or not centralizing the power in this manner will pay, is a question that must be carefully considered in each case. With new installations, all these conditions should be fulfilled. But the installation of a single central machine, to drive all the pumps and transmit all power is not advisable, on account of the high cost of installing and the greater certainty of work when using a number of small machines. The reliability of machinery is a most important consideration in a sugar factory. Every stoppage causes great losses by increasing the cost of production and maintenance, and causes at the same time, sugar losses in the beets.

The installation of new machinery is not to be recommended unless the old machinery produces more exhaust steam than can be utilized in the evaporators. In such cases, a certain amount of centralizing should be done, and a sufficient number of cylinders should be condensed into one, in order to decrease the amount of exhaust steam. The consumption of steam in the cylinders, should be reduced so that they produce only sufficient exhaust steam for the evaporators. All the engines should be properly adjusted and frequently and carefully tested with indicators. Most of the exhaust steam can be utilized in the

reheaters and evaporators, particularly when expanded to 3/4 atmosphere. In factories with much exhaust steam, the triple effect evaporators should be replaced by quadruple effects, in which the first body is used for a preheater. The cost of fuel can be readily decreased by methods of this kind, but care must be taken in altering one station, not to hinder the work of another, for example, the centralization of machinery is very apt to necessitate a change in the boiler house, and cause losses of steam in other places, without decreasing the amount of exhaust steam.

The practice of superheating steam, which gives very good results in most industries, is not satisfactory in beet sugar factories, except under the unusual conditions of too great an amount of exhaust steam. This condition is not met with in properly constructed sugar houses. Superheating steam is of much importance in decreasing the condensation losses in the piping and cylinders. The superheating can be done with advantage with the flue gases when these are sufficiently high, but they are as a rule only 250 - 300° C., which is too low to superheat the steam properly. The superheating apparatus, should be placed at the rear of the fire box, where the gases have a temperature of 500 - 600°C. Numerical data on the advantages of superheating steam in sugar factories is lacking, and it is doubtful if such installations are economical, on account of the high costs of installation and repairs, and the high maintenance and severe deterioration between campaigns. Superheated steam,has besides, many difficulties, the cylinders have to be freely lubricated with expensive oils, and the design of the machinery has to be well adapted to the high pressure work. In sugar manufacture, only the steam for the engines can be superheated; that used for heating purposes must never be so treated.

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General Heat Losses. The heat in the steam and other material is utilized, when there is enough of it to reheat water, juice, etc., but with every transfer of heat, there is a decrease in temperature and a loss of energy. The quadruple effect evaporator is the only practical apparatus for heating purposes. It is impossible to utilize vapor or liquids for evaporation, below a temperature of 70°C., and for heating below 50 - 60° C. In the latter case, only very small amounts of heat are available, and then only with liquids very much colder than the heating medium. In consequence, all quantities of heat which are below these temperature limits, should be looked upon as lost. They can be calculated from the waste waters and waste products of the factory, by noting the weights of these products and figuring accordingly. It is impossible to calculate the amount of heat lost in cooling, in the various types of apparatus, such as juice tanks, piping etc., and in the vapors, juices and waters etc., nor can one estimate the amount lost in the steam in heating the saturation and steaming out apparatus and centrifugals, and through dilution of liquids.

An approximate calculation, (See appendix 2.) shows that of the heating units remaining in the steam after deducting the losses in the steam pipes and engines, about 2/3 rds., are lost in the condenser water, the waste waters of the diffusion battery and filter presses, and in the excess vapors of the factory. The remaining 1/3 rd., of heat units are not directly determinable. The importance of decreasing the cooling losses, and losses by escaping steam, is very apparent, and all possible precautions should be taken to prevent such wastes.

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CHAPTER XXVI.

THE SUPERVISION OF THE WORK AND THE DETERMINATION OF THE LOSS OF SUGAR.

A description of the methods for the chemical control of the factory, is not within the scope of this book; but the importance of a correct and careful chemical control, cannot be too highly estimated. The control should be maintained day and night, but the investigations should be done at night. When a chemical control is established in a factory, total reliance must not be placed on it, for in practical work, the quality of the juice must be noted irrespectivoly of the chemical analyses, for the latter are always tardy indications of difficulties. The practical care of the factory cannot be followed along any general rules. A great many outward signs will show, immediately, any abnormal work. The results of chemical investigations, depend on the methods of research, and many apparent mistakes in the work, according to the chemical tests, are due wholly to the method in which the tests are made, or to the lack of a sufficient number of tests to make a correct average. The work of the chemist should not be confined to the laboratory; as much time as he can spare should be devoted to the factory experimenting with processes, but these should be overseen personally in order to insure their correctness. Superintendents and chemists, if not combined in one man, must work hand in hand. Clear and correct conclusions must be drawn from the chemical work. The value of chemical control must be not only in noting mistakes, but being able to correct them.

The investigations made in the laboratory to explain any of the difficulties of the work, must be done with the greatest of care, under precisely the same conditions as exist in the house, otherwise the results are useless for practical work, even harmful, since they lead to wrong conclusions. Much of the false representation of the

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The investigations made in the laboratory to explain any of the difficulties of the work, must be done with the greatest of care, under precisely the same conditions as exist in the house. Otherwise the results are useless for practical work. Even hasty, minor tests may lead to wrong conclusions. Much of the false appearance of the

work of one factory, in comparison with another, is due to the unreliability of the investigations, and further, results of past years cannot be compared with those of today on account of the change in methods.

The other extreme, of laying all the difficulty of the work to the quality of the beets, is of course unwarranted. It is true that beets vary in different campaigns, and even at different times during the same campaign, but in general, beets work enough the same for a factory to work to its capacity, unless the beets are badly rotted, frozen, or otherwise injured. In many cases the quality of the beets have nothing to do with the difficulties of the work, which can be attributed to other causes entirely. The difficulties at the beginning of the campaign are not so often due to poor, and unripe beets, as to the mistakes of the untutored workmen. The most important part of the chemical control, lies in determining the loss of sugar. The difference between the amount of sugar in the beets and that derived from the fillmass is the total amount of sugar lost in manufacture. When the weight and the polarization are determined directly, this loss is usually higher than the sum of the losses in the waste products. In consequence, one has to distinguish between the determinable and undeterminable losses.

To determine the amount of sugar entering the house, the beets have to be accurately weighed and the average sugar content carefully determined. In countries where factories do not weigh their beets, the amount is determined indirectly, by the number of diffusion cells, or by the weight of the diffusion juice. With this method, there are no undeterminable losses in obtaining the juice, so that the amount of sugar produced, plus that in the waste product, is considered the total amount of sugar in the beets. No degree of precision can be obtained by this method, and it is remarkable that in the sugar industry,

in which so much importance is attached to the chemical control, that the small costs for this important data should be neglected.

The amount of sugar in the cossettes should be determined by standard methods, such as the alcohol extraction, which must be controlled by an after extraction, or by hot water digestion under proper conditions. In these investigations, not merely the amount of polarizable material must be determined, but the amount of sugar as well. Less careful methods which give lower percentages of sugar and apparently better practical results, should under no circumstances be countenanced. Since with present methods of working the fillmass, a pure 1st.. product is not obtained, the amount of sugar recovered must be estimated from the weight of 1st., product sugar, and the space occupied by the 2nd.; product material, or when sugar is introduced, the estimate must be based on the weight of the salable sugar and the molasses. The longer a campaign runs the more difficult it is to analyze the syrups, but complete analyses should be made every week, or at least several times during the campaign. Small quantities of syrup which have to be carried over from one week to another, can be calculated as fillmasses. No difficulty is experienced in getting accurate tests of the sugar and syrup fillmasses. The determinable losses, are those of the diffusion work, lime cake, and the condensor water. For these are the only losses which can be precisely measured in the waste products. There are of course, many other known losses, the quantity of which it is impossible to calculate. The most important of these are the losses by decomposition of sugar in evaporation and boiling, losses in the filter cloths, mechanical losses of entrainment, and leaks and overflows in the house. All these losses together do not amount to much, rarely more than 0.01% of the weight of the beets. Naturally, when working normal alkaline juices, there are comparitively

few mechanical losses of sugar. There are in consequence, no rational explanations for the high undeterminable losses which exist in every factory, in which a careful chemical control is established. Great care is essential in order to determine correctly, the known losses. Any carelessness in the determinations, or the tests, will make all the losses too small. After clean-ups, a small loss of sugar is not always an indication of good work, such figures should be held in distrust. At the close of a campaign, factories with good chemical control, show a total loss of 1.0 to 1.5 % on the weight of the beets; of 0.5 to 0.7% are known losses, the other half are indeterminable, and partly inexplicable. When it is not of great importance to the factory to know the amount of loss, it is just as well to leave the actual losses unknown, for these would be apt to figure very high on sugar. One must be certain though, that these losses are not actual sugar losses, but polarization losses, for which no sufficient explanation can be given. Only the most important sugar losses should be taken into consideration, and little importance should be attached to the sugar losses, on account of their unreliability. Since all of the determinable losses have to be recovered from the waste products, the greatest care, most precise chemical control must be established over these products, in order to obtain the proper averages.

The principle determinable losses in the diffusion battery, are in the cossettes and drain water. Obtaining correct averages of the amount of sugar in the pulp is very difficult, not only on account of the differences in the size of the diffusion, but on account of the variation of the amount of sugar left in the pulp. The weight of the wet cossettes cannot be directly determined and the amount of water they contain varies from 80 to 100%, hence, the tests of the pulp should be used only for the diffusion control and not for the determination of the losses for which the pressed pulp and the water from the same should

be used. The weight of the pressed pulp can be determined very accurately and a more correct average can be made than with wet material; at the same time it is thoroughly mixed in the presses and conveyors. The sugar tests should be done by the hot water digestion method, which yields very correct results. It is very easy to obtain good averages from the press waters, particularly when using constant sampling apparatus. All these losses are very small and figure only in the hundredths of 1% on the weight of the beets.

The scumsfrom the saturation are very difficult to analyze and vary enormously from one press to another. The samples must be taken from numerous frames in each press, though a more certain method is to take the samples from the lime cake scrolls. Where the cake is mixed with a little water, very good averages can be obtained by figuring on the weight of the mixture, it being very easy to determine the water content, or specific gravity of the same. The weight of the cake is usually determined from the capacity of the frames in the press. Another good method, is to figure on the weight of a cake from the weight of lime used for defecation; this varies from 3.5 to 4 times as much as the lime, according as the cake is dry or wet.

The condensor waters can be easily sampled by continuous "drop samples", and the amount can be accurately determined from the vapors condensed and the amount of condensor water used.

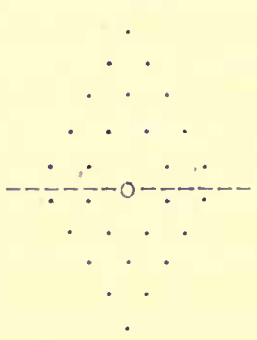
The losses of a factory, should be about as follows:-----

On 100 parts of beets -----	Total losses		1.2% on beets.			
In the pressed pulp	50%	with	.5% Pol.	=	.25%	on beets.
" " press water	40%	"	.2% "	=	.08%	" "
" " battery drainage waters	130%	"	.1% "	=	.13%	" "
" " 1st., Lime cake	8%	"	1.5% "	=	.12%	" "
" " 2nd., " "	5%	"	4.0% "	=	.02%	" "
" " Condensed water	600%	"	.00	=	.00%	" "
					.60%	
			Undetermined		.60%	
			Total.- - - - -		1.20%	on beets.

In factories in which the diffusion juice is measured accurately and properly tested, the total losses of the diffusion work can be determined with precision. Since the juices undergo very rapid decomposition, they must be analyzed not later than half an hour after sampling, or better still should be treated with acetate of lead or Mercuric chloride immediately. It is still an open question as to whether or not there are any large undeterminable losses in the diffusion work. Practically, it makes little difference whether or not this is so, for such losses would be apt to be wholly polarization losses, and of theoretical interest only. No large losses occur in the battery under normal work with healthy beets, and quick work, but any delays are apt to start inversion and give a large percentage of organic impurities. It is very improbable that ferments or bacteria have any opportunity to start any reducing action, or to influence the work deleteriously.

Mechanical losses occur sometimes in the saturation and evaporators, through the steam pipes used for heating. All such pipes with their drains should be readily available and well protected. Losses of sugar which get back to the boiler house are readily detected in the odor of the steam and the color of the water in the boilers. Condensed waters which are not used in the boilers must be carefully tested for sugar.

If all of the above mentioned precautions are observed, there is little likelihood of mechanical losses occuring unnoticed.



CHAPTER XXVII.

GENERAL CRITICISMS ON THE MANAGEMENT AND SUPERVISION OF A BEET SUGAR FACTORY.

A beet sugar factory produces out of a comparitively complex raw product of nature, a purified product, which in most factories needs further purification before it is ready for consumption.

Beet sugar factories cannot afford to lay any stress upon the beauty of their buildings, their interior or their machines. The principle features of such houses should be their unity and cheapness. Unessential improvements cost money, which is not returned in any way, and does not decrease the cost of obtaining sugar from the beets, nor aid in obtaining a better product. On account of the few short months of a campaign, it is almost impossible to realize any benefits from such investments. The operations and methods of handling a factory should depend on the bounties and commercial methods of the country in which the factory is located. Where the bounty is based on the weight of the beets, the greatest care must be taken to decrease the losses at all of the stations, for the sugar has more than double the ordinary value. The number of diffusion cells and filter presses should be carefully measured. Where the bounty is based on the juice, the pulp does not need to be worked so low, though care must be taken to obtain the juice at a proper temperature and purity, to correctly estimate the bounty. The press cakes should be carefully sweetened and all losses by entrainment and leaks should be guarded against carefully. Where the bounty is based on the final products of sugar, there need not be such great worry over the losses, though of course, the losses should not be allowed to overstep the proper limits. A larger yield obtained by accelerated work is more profitable than a small loss with a high price sugar. The commercial handling of the sugar depends on

its physical properties and influences to some extent, the work in the sugar house. Where it is desirable to make an alkaline sugar, the work previous to the centrifugals must be carefully watched.

A factory should be provided with ample light and ventilation, and should be so arranged that the whole building can be overlooked. The machines and apparatus should be durable and set on firm foundations; whether or not they are of modern or pleasing form, is of little importance. When the machines have sufficient power without creating any excess exhaust steam, and at the same time perform their work properly, there is nothing else essential. The work of a sugar superintendent is firstly-- the manufacture of sugar, and secondly, but of no less importance, should be his attempts to watch and better the beets and the juices. These things should absorb all of his time and energy, and he should not be compelled to watch his engines and machinery, for this is by rights the work of the chief engineer. Irregularities in mechanical work must be overcome as quickly as possible, for the thing to be kept in mind is unceasing and regular work, in order to operate cheaply and correctly. Every stop costs money, on account of waste of labor, the useless consumption of fuel, the deterioration of the juices, and loss of sugar. The quicker the juice is worked, the better it is, in consequence, none of the apparatus or stations should be too large, for the juice should run in a constant stream. When a station is out of proportion to the rest of the house, it should either be enlarged or decreased in size. In enlarging a station, great care must be taken to make it fit the other portions of the house. All stations should be large enough to allow some elasticity in the work; and all conveyors should far exceed in capacity, the average amount of work they have to perform.

By enlarging a factory, the cost of working can, within certain limits, be decreased. When a factory obtains as many beets as they need for a normal campaign, the possibilities for enlargement come up with possibilities of increased beet territories, though it is often advantageous to build factories in the new districts. When a factory does not obtain a sufficiently large crop, its capacity should not be decreased but the campaign should be shortened, in order to maintain the cost of working as low as possible. Under such conditions, the beets do not have to be siloed and can be harvested at the time of their highest sugar content. If the duration of work is decreased to 6 weeks, on enlarging a factory, the enlargement does not pay, in fact is injurious, for the beet contractors cannot harvest in so short a time. In such cases it is better to improve a factory, in order to obtain higher yields. Improvements to the factory should be made every year; in most cases 15 to 20% of the original capital should be set aside for this purpose. The improvement should not be made on all the stations at one time, in order to locate where the money can be invested best so as to obtain the highest yield. Care and conservatism always succeed, and there is nothing to be gained from rash conclusions, the greatest advantages are often forthcoming from simple methods. No hesitation should be made in installing improvements from which there is a certain gain to be derived.

For careful work, cleanliness of the factory, the workmen, and the apparatus, must be observed. Not only the outside portions of the machinery must be kept clean, but the working parts as well. When the interiors of all tanks and apparatus are properly kept, great difficulties and hindrances of the work are forestalled. The total costs of working, for a campaign, vary, naturally, in every factory,

though there should be little variation in each factory from year to year. With the present high cost of fuel the total campaign cost, per 100 kg., of beets worked should not be more than,

Working expenses - - - - - - - - -	10 to 12 Pfg.
Fuel - - - - - - - - - - - - - - -	8 " 10 "
Lime (Limestone and Coke) - - -	1 " 3 "
Oil and tallow - - - - - - - - -	4 " 5 "
Filter cloths - - - - - - - - - -	4 " 7 "

The total yearly costs depend on the cost of working, repairs, and maintenance. The more beets are worked the less the cost will be per 100 kg. Factories with small crops have a total cost of 70 - 90 Pfg; those with medium crops have from 60 - 70 Pfg., while the largest factories reduce their cost to 50 pfg. The size of the factory has not as much to do with the cost as the amount of beets worked, compared with the cost of the factory.

For the practical supervision of the factory, it is often useful to tabulate the results of each station; for example, the amount of beets worked, the number of diffusion cells filled, the time of diffusion, the pressure of each cell, the Brix of the diffusion juice of each measuring tank, the number of presses emptied, the density and alkalinity of the juices, and all the data concerning the boiling, crystallizing, and centrifuging of the fillmasses, together with all the data of the boiler house and lime kilns. These records serve as ready means for detecting errors and difficulties. In conjunction with this, technical records of the factory must be kept, containing all of the technical data, the complete record of all the results and investigations in the laboratory, and all the data concerning the work with references to the coal, coke, stone, lime, cloths, acids, oil, sacks etc. These records should contain also, notes on the harvesting, siloing, and storage of the beets, and the qualities of the sugar. The more precisely and carefully these results are recorded, the more value they have.

In many factories, samples of the juices and fillmasses are taken only at stated intervals, and are consequently of only slight value. These results are illusory because the foremen are apt to pick only the best samples; in consequence, it is best to frequently do ones own sampling.

The repair period should be of no less importance to the superintendent than the campaign. A general clean-up of all machinery must be made. All large repairs which necessitate the removal of machinery from the factory should be attended to immediately after the close of the campaign, so that the work can be done carefully. The small repairs which can be done in the work shops, should be distributed throughout the time between campaigns, in order to keep the same amount of labor during the entire period. As many of the small repairs as possible should be done at the factory in order to avert the excessive costs of machine-shops. The metal work should all be protected from rusting by covering with fats and paints, and should be protected from dust by cloth covers.

When in doubt as to which portions of machines and apparatus to repair, or renew, the parts which show any likelihood of breaking down during campaign, should be attended to first. Machinery on which the work of the factory depends, must be in faultless condition, particularly the heavy inaccessable parts. care in repairing and reassembling the machinery will prevent many embarrassing troubles during the campaign.

The boilers and all the boiling and heating apparatus should be carefully examined in regard to strength and freedom from leaks. Coils and heating bodies should be tested with a water pressure of from 1 - 2 atmospheres higher than that of the steam pressure. With apparatus using low pressure steam and heating, the pressure of the

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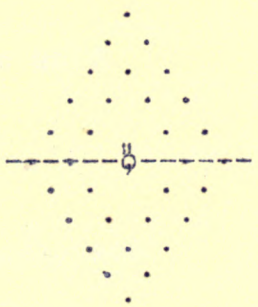
The boilers and all the boiling and heating apparatus should be carefully examined if required to strength and freedom from leaks. Boils and heating bodies should be tested with a water pressure of from 1 - 2 atmospheres higher than that of the steam pressure. With apparatus using low pressure steam and heating, the pressure of the

tank waters (about 1 atmosphere) is sufficient for this testing, the air and drain cocks must be frequently used. Both the steam and the juice spaces must be tested with all the evaporator apparatus, which is boiled out with acids. All heating pipes and coils must be cleaned and freed from scale, as well as the condensors, carbonations, pumps, tanks, and filter presses. All valves in the diffusion, saturation, presses, and evaporators, must be renewed. Where frosts occur between campaigns, steam cylinders, pipes and valves must be taken apart in order to thoroughly drain them and prevent water from freezing and causing breaks.

If it is desirable to keep the pipes and apparatus in proper order, it is a good idea to paint them the color of the fluids which flow through them. Before the beginning of the campaign, all engines, apparatus and piping, must be tested singly and together, and finally the whole factory should be given a complete test with water, just as though it were juice. If everything goes smoothly, a campaign with few difficulties can be relied upon.



CHAPTER XXVIII.

THE VALUE AND USE OF THE WASTE PRODUCTS.

The waste products of a beet sugar factory, consists of the lime cakes in the filter presses, dirt in the beets from the storage, and beet rootlets and tailings.

The press cake, incorrectly called the defecation scum, is valuable in most localities as a soil fertilizer. It consists mainly of carbon-dioxide, lime, phosphoric acid, nitrogen and potassium. The percentage in which these compounds are contained depend on the water content of the cake, the amounts of the materials in the beets, and on the amount of lime. The cake contains from 40 to 50% water. With the same amount of water under the same conditions, the cake contains mostly phosphoric acid and nitrogen, which is obtained by the use of lime in defecation. The same amount of phosphoric acid and nitrogen is obtained from a 7% cake, using 1-3/4% lime, as when using 3% of lime in a 12% cake. In consequence the use of different amounts of lime is the principle cause of the variation in the composition of the cake. The dry substance of the cake consists as a rule of:-

Phosphoric acid	1.0 to 2.5%
Nitrogen	2 " 4%
Potassium	.05 ".3%
Calcium Carbonate	55.0 "15.0%
Organic matter	10.0 "15.0%

The value of the press cake depends largely on its physical properties. As obtained in the factory, it acquires a smeary consistency, which prevents it from being readily distributed on the soil in a fine condition. By long storage in piles or by working

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Phosphoric acid 1.0 to 2.5%

Nitrogen .5 " 1.5 "

Potassium .05 " .3%

Calcium Carbonate 60.0 " 75.0%

Organic Matter 10.0 " 15.0%

The value of the press cake depends largely on its physical properties. As observed in the factory, it acquires a sandy consistency, which prevents it from being readily distributed on the soil in a fine condition. By long storage in piles or by working

with dirt, it becomes dry and friable, and then serves as an excellant fertilizer. By mixing the cake with a finely ground lime, a pulverized product is obtained which is easily strewn on the soil and enriches ground which is poor in lime. Many factories mix the cake with water to a mushy mass, with the dirty water of the beets, and then add the fine loam adhering to the beets. This gives an excellant composition, which is very much sought after by the farmers in the vicinity of the factories. On account of its weight, it cannot be transported without undue expense.

The dirt from the beets is always very much in the way, but on account of its value as a fertilizer, the factory can have it removed for almost nothing. The tails and rootlets of the beets are used for feed, and are usually paid for as such; though they are often worked these days in conjunction with the cossetts, or are dried separately.

The waste waters are a source of considerable trouble and expense to all factories. The waste water is made up of the wash waters from the presses, and the beets, the drain water from the diffusion and the pulp presses. As a rule, large quantities of clean water from the overflow-pumps or condensers, are mixed with this, though it is best to run it off separately. The amount of waste water from 100 kg. of beets is about as follows:

Flume and wash water ----------500 to 700 Liters.
Drain water from the diffusion-------100 " 150 "
Drain water from the pulp presses---- 30 " 50 "
630 " 900 "

The amount of waste water from a factory working 1,000,000 pounds of beets a day is 7,500 to 8,500 cbm. When the drain water from the diffusion is used to float in the beets, the amount of waste water is decreased. After the roots and grasses are separated, the

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waste water from 100 Kg. of beets is about as follows:

Flume and wash water ----------500 to 700 liters

Drain water from the diffusion----100 " 150 "

Drain water from the pulp presses--- 30 " 80 "

630 " 930

The amount of waste water from a factory working 1,000,000
pounds of beets a day is 75,500 to 94,000 cubic feet. When the drain water
from the diffusion is used to float in the beets, the amount of waste
water is decreased. After the roots and cossettes are washed, the

waste waters must be cleaned mechanically. The material which floats on top is skimmed off. To accelerate the settling of the fine light material that hangs in the liquid, chemical precipitates must be used to carry down this matter. Milk of lime and salts of iron are used for this purpose. In conjunction with milk of lime, iron salts form oxyhydrates, causing a precipitate. Milk of lime alone, makes the water alkaline and decomposes many of the albuminoids and other organic matters of the scums, making a portion of them soluble and precipitating many of the rest. The water coming from the clarifiers, though clear, is not pure, for it contains all sorts of substances dissolved in it, many of which ferment and foul. Chemical methods do not affect this material; the best thing that can be done is to add milk of lime to make the solution alkaline, and so for a while prevent decomposition? The waste waters can be purified by simple spraying, by which means the plant growth and earth bacteria are deprived of their nourishment, and are converted into more stable substances. Since this organic matter can exist only with heat, it flourishes very little in autumn or winter, and spray filter serve at best only to clarify the water mechanically. The question of the value of the entire purification of the water is yet unsolved. The water need not ever be entirely purified, and only partially so as the case demands. Where the waste products flow into large streams, a simple clarification is all that is essential; the organic matter is purified in a very short while in the self purification of the streams. The smaller the water courses and the less the waste waters are diluted, the more it has to be purified, in order not to be obnoxious. Under district limitations, the waters have to be clarified by the use of chemicals. Factories which have many

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difficulties in purifying their water will be greatly relieved by modern methods of diffusion and press work.

Waste waters are injurious to men and cattle, and in small streams they present various phenomena. Fish are not injured by it directly, but by the development of fungus growths. The fungus becomes foul and developes hydrogen-sulphide in sufficient quantities to kill the fish. The amount of purification essential, depends on the kind of organic matter that develops in the water. There are normally three water fungi, namely, Leptomitus, Sphaerotilus, and Beggiatoa. Leptomitus is the first to develop in comparitively pure water, Sphaerotilus occurs only in very impure waters, while Beggiatoa develops only in foul and stinking water; these two latter fungi characterize an insufficient purification of the water.

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CHAPTER XXIX.

ANALYSES OF BEETS, JUICES, AND SUGAR PRODUCTS.

The juices, syrups, fillmasses and sugar of various factories had the following average composition — during the campaign 1898/99.

(a) Juices and Syrups.

	Beets				Thick Juice		Final syrups from		
	Hot Water Digestion	Diffusion Juice	1st Saturation Juice	Thin Juice	Unsaturated	Saturated	1st Prod.	2nd Prod.	Molasses
Brix	—	14.4	—	12.2	—	53.3	77.4	76.4	82.8
Polarization	14.66	12.2	—	10.9	—	48.0	56.9	49.1	47.8
Apparent Purity	—	84.7	—	89.3	—	90.1	73.6	64.3	57.7
Alkalinity, Phenolphtalein	—	—	0.091	0.049	0.142	0.049	0.11	0.11	0.08
" Rosolic Acid	—	—	0.11	0.067	—	0.075	—	—	—
Lime (Percent by Volume)	—	—	—	0.043	—	0.16	—	—	1.6
Invert Sugar	0.17	0.18	—	—	—	—	—	—	—
Acid (% ccm. Normal Acid) Phenolpht.	—	2.1	—	—	—	—	—	—	—

(b) Fillmasses, Sugar and Molasses.

	Thick Juice	Fillmasses			Molasses	Raw Sugar		
		I Boiled with Syrup	II	III		I	II	III
Polarization	47.9	83.5	67.1	58.7	47.8	96.1	92.1	90.8
Water	47.7	7.55	10.42	11.5	21.83	1.56	2.56	2.70
Ash (SO_3)	1.72	3.48	8.52	—	11.78	0.93	2.07	2.81
Organic Nonsugar	2.67	5.47	13.96	—	18.59	1.47	3.27	3.69
Real Purity	91.6	90.3	74.9	66.4	61.1	—	—	—
Alkalinity Phenolphtalein	0.039	0.064	0.12	0.14	0.08	0.011	0.035	0.030
Lime	0.12	0.27	0.62	0.76	1.6	—	—	—
On 100 Polarized Ash	3.6	4.1	12.7	—	24.6	—	—	—
" " " Organic Nonsug.	5.6	6.6	20.8	—	38.9	—	—	—
" " " Lime	0.25	0.32	0.93	1.29	3.3	—	—	—
" " " Alkalinity	0.08	0.08	0.17	0.24	0.16	—	—	—
Organic Nonsugar Ash	1.55	1.57	1.64	—	1.58	1.58	1.60	1.32

CAMPAIGN 1902/3

(a) Juices and Syrups.

	Beets				Thick Juice			
	Hot Water Digestion	Diffusion Juice	1st Saturation Juice	Thin Juice	Unsaturated	Saturated	Final Syrup	Molasses
Brix	—	14.0	—	12.6	—	59.6	81.0	83.8
Polarization	14.91	12.1	—	11.5	—	55.0	60.6	49.8
Apparent Purity	—	85.5	—	91.5	—	92.3	74.9	59.4
Alkalinity Phenolphtalein	—	—	0.093	0.041	0.133	0.045	0.142	0.18
" Rosolic Acid	—	—	0.11	0.051	—	0.064	—	0.26
Lime (Percent by Volume)	—	—	—	0.035	—	0.101	—	0.60

(b.) Fillmasses, Sugar and Molasses.

	Thick Juice	Fillmasses		Molasses	Raw Sugar	
		Boiled with H. Syrup	II		I	II
Polarization	54.9	84.7	70.4	49.7	96.15	94.0
Water	41.0	6.93	7.32	19.33	1.40	1.85
Ash (SO_3)	1.63	3.24	8.56	11.92	0.88	1.60
Organic Nonsugar	2.47	5.13	13.72	19.06	1.56	2.55
Real Purity	93.1	91.0	75.9	61.6	97.5	95.8
Alkalinity (Phenolphtalein)	0.034	0.062	0.137	0.14	0.013	0.020
Lime	0.080	0.16	0.40	0.60	—	—
On 100 Polarized Ash	3.0	3.8	12.2	24.0	—	—
" " " Organic Nons.	4.5	6.1	19.6	38.3	—	—
" " " Lime	0.14	0.19	0.57	1.2	—	—
" " " Alkalinity	0.06	0.11	0.19	0.28	—	—
Organic Nonsugar Ash	1.52	1.60	1.61	1.60	1.77	1.62

POLARIZATION AND ALKALINITIES

of Juices, Syrups, Fillmasses and Sugar of Factories for Different Years

	METHOD OF BOILING									
	Blank Boiling						Boiling to Grain			
	1896/97		1897/98		1898/99		1900/01		1901/02	
	Pol.	Alk.	Pol.	Alk.	Pol	Alk.	Pol.	Alk.	Pol.	Alk.
First Saturation Juice	—	0.082	—	0.072	—	0.087	—	0.084	—	0.089
Second " "	—	0.021	—	0.043	—	0.048	—	0.043	—	0.039
Thin Juice	10.2	0.021	10.7	0.042	10.9	0.047	10.5	0.041	10.1	0.034
Unsaturated Thick Juice	—	—	—	0.100	—	0.110	—	0.095	—	0.093
Saturated " "	52.5	0.034	51.5	0.035	48.0	0.039	50.6	0.030	53.8	0.033
Fillmass I boiled with Syrup	82.6	0.038	83.3	0.063	83.5	0.064	83.5	0.044	82.2	0.043
Raw Sugar I	95.2	0.006	96.0	0.011	96.1	0.011	96.4	0.011	96.4	0.008
Final Syrup I	54.2	0.100	57.9	0.109	56.5	0.110	59.0	0.046	58.9	0.104
Fillmass II	63.6	0.077	66.3	0.108	67.1	0.130	68.5	0.092	67.0	0.082
Raw Sugar II	93.2	0.006	93.5	0.016	92.1	0.015	93.2	0.013	93.7	0.012
Fillmass III	55.5	0.092	59.4	0.132	58.7	0.140				
Raw Sugar III	93.1	0.007	93.0	0.024	90.8	0.010				
Molasses	48.3	0.080	48.2	0.130	47.8	0.080	49.5	0.075	50.5	0.103

ANALYSES OF BEETS FROM DIFFERENT PROVINCES

Tested on September 22nd 1898.

(Herzfeld, Deutsche Vereinszeitschrift 1898. S. 828)

PROVINCE	Average Weight		Ratio of Beets To Tops	Contents of Beets in				
	Beets	Tops		Sugar	Total Ash	Soluble Ash	Nitrogen	Marc
Schlesien	416	516	1:1.24	13.9	0.95	0.83	0.24	4.95
Pommern	340	217	0.64	16.7	0.72	0.45	0.20	4.37
Sachsen 1.	458	363	0.71	16.6	1.01	0.82	0.21	5.15
" 2.	330	300	0.94	14.9	0.82	0.60	0.16	5.23
Hannover	412	321	0.78	15.2	1.03	0.48	0.17	4.84
Rheinland	352	438	1.22	13.7	1.12	0.59	0.18	4.71

ANALYSES OF DIFFUSION JUICE MOLASSES and FILLMASSES OF BOHEMIAN FACTORIES FOR CAMPAIGN 1898/99.

(Amerllk, Bohm Zeitschrift 1900. S.208–264 and 1901. S.247.)

Factory	Diffusion Juice a	b	c	d	e	Fillmass a	b	c	d	e
Polarization	—	—	—	—	—	90.7	90.5	87.6	87.15	85.75
Water	—	—	—	—	—	3.06	4.72	4.55	4.88	6.02
Ash (Carbonated)	—	—	—	—	—	2.14	2.16	2.49	2.66	2.32
Organic Non sugar	—	—	—	—	—	4.10	3.62	5.36	5.32	5.91
Quotient	—	—	—	—	—	93.5	93.9	91.8	91.6	91.2
Organic Nonsugar : Ash	—	—	—	—	—	1.9	1.7	2.1	2.0	2.5
Alkalinity Phenolphtalein	—	—	—	—	—	0.017	0.004	acid	0.028	acid
	On 100 Parts Dry Substance									
Total Ash	3.77	3.09	3.81	3.79	3.23	2.21	2.24	2.61	2.80	2.47
Potassium	1.34	1.36	1.72	1.55	1.40	1.25	1.19	1.37	1.59	1.41
Sodium	0.12	0.09	0.16	0.19	0.11	0.15	0.20	0.27	0.19	0.13
Calcium	0.06	0.04	0.03	0.06	0.12	0.01	0.02	0.02	0.03	0.04
Phosphoric Acid	0.37	0.49	0.64	0.49	0.35	0.005	0.011	0.003	0.014	0.009
Sulphurous "	0.22	0.17	0.18	0.24	0.24	0.13	0.17	0.10	0.14	0.17
Chlorine	0.05	0.08	0.07	0.08	0.09	0.10	0.06	0.07	0.07	0.07
Total Nitrogen	0.87	0.90	0.75	1.31	0.80	0.37	0.41	0.56	0.45	0.57
Albuminous Nitrogen	0.30	0.28	0.26	0.29	0.32	0.03	0.03	0.05	0.04	0.04
Ammoniacal "	0.11	0.15	0.09	0.11	0.10	0.06	0.03	0.06	0.03	0.02
Amido Acid "	0.44	0.21	0.33	0.38	0.33	0.24	0.26	0.40	0.27	0.44
Oxalic Acid	0.40	0.80	0.91	0.66	0.66	—	—	—	—	—

MOLASSES

Factory	1.	2.	3.	4.	5.	6.	7.	8.
Polarization	47.2	48.0	47.4	46.6	49.0	47.4	47.2	51.1
Saccharose (According to Herzfeld)	48.8	49.8	47.9	47.9	49.2	47.7	47.5	51.5
Water	21.64	20.35	20.66	18.14	16.87	19.91	22.49	18.80
Ash (Carbonated)	8.68	9.14	8.71	10.10	10.95	10.49	9.54	9.11
Organic Non Sugar	20.88	20.71	22.77	23.86	22.98	21.90	20.43	20.63
Quotient	62.3	62.5	60.3	58.5	59.2	59.6	61.3	63.4
Organic Non Sugar : Ash	2.4	2.3	2.6	2.4	2.1	2.1	2.2	2.3
	On 100 Parts Dry Substance							
Total Ash	11.08	11.48	10.98	12.37	13.18	13.10	12.31	11.21
Potassium	6.29	6.53	6.26	6.66	7.07	6.60	6.71	6.20
Sodium	0.84	0.87	0.81	1.00	1.09	1.41	0.72	1.09
Calcium	0.14	0.22	0.19	0.14	0.21	0.19	0.09	0.09
Magnesia	0.04	0.04	0.04	0.21	0.03	0.04	0.05	0.05
Phosphoric Acid	0.01	0.03	0.04	0.04	0.08	0.07	0.04	0.10
Sulphurous "	0.18	0.21	0.17	0.56	0.37	0.31	0.15	0.16
Chlorine	0.38	0.42	0.39	0.48	0.48	0.50	0.43	0.37
Total Nitrogen	2.22	2.47	2.37	2.62	2.50	2.40	2.41	2.24
Albuminous Nitrogen	0.22	0.18	0.26	0.19	0.14	0.13	0.29	0.17
Ammoniacal "	0.07	0.06	0.04	0.09	0.07	0.08	0.07	0.05
Amido Acid "	1.24	1.36	1.15	1.47	1.59	1.63	1.22	1.46
Nitrate "	0.06	0.07	0.06	0.02	0.09	0.02	0.04	0.02

Appendix I.

F O R M U L A E A N D T A B L E S.

The following figures, formulae and tables are of interest only to technical sugar men. This compilation is of value, in that no other works or hand books on the sugar industry contain them, except in partial or unsatisfactory form. Only such data is given as is of value for the technical control of the work.

F O R M U L A E.

1. To calculate the weight of water (W) which must be evaporated from G kg thin juice of s Brix, in order to obtain a thick juice of S Brix.

$$W = G\ (1 - \frac{s}{S}).$$

2. To calculate the amount of thick juice or fillmass (F) of S Brix that can be derived from G kg thin juice of s Brix.

$$F = G\ \frac{s}{S}$$

Note: For accurate calculations, the real dry substance must be used instead of the apparent Brix.

3. Yield Formulae.

Ft Zt St = Dry substance of Fillmass, Sugar and Syrup.

Fp Zp Sp = Polarization of Fillmass, Sugar and Syrup.

Fq Zq Sq = Quotient of Real Purity of Fillmass, Sugar and Syrup.

X = Percentage Yield.

(a) Formula of Hulla-Suchomel

$$X = 100.\ \frac{Ft(Fq - Sq)}{Zt(Zq - Sq}$$

(b) Formula of Schneider

$$X = 100.\ \frac{Fp - Sp}{Zp - Sp}$$

(c) Formula of Neumann

$$X = 100.\ \frac{Ft - St}{Zt - St}$$

FORMULAE AND TABLES.

The following figures, formulae and tables are of interest only to technical sugar men. This compilation is of value, in that no other works or hand books on the sugar industry contain them, except in partial or unsatisfactory form. Only such data is given as is of value for the technical control of the work.

FORMULAE.

1. To calculate the weight of water (W) which must be evaporated from G Kg thin juice of s Brix, in order to obtain a thick juice of S Brix.

$$W = G\ (1-\frac{s}{S}).$$

2. To calculate the amount of thick juice or fillmass (P) of S Brix that can be derived from G Kg thin juice of s Brix.

$$P = G\ \frac{s}{S}$$

Note: For accurate calculations, the real dry substance must be used instead of the apparent Brix.

3. Yield Formulae.

Pt Zt St = Dry substance of Fillmass, Sugar and Syrup.

Pp Zp Sp = Polarization of Fillmass, Sugar and Syrup.

Pd Zd Sd = Quotient of Real Purity of Fillmass, Sugar and Syrup.

X = Percentage Yield.

(a) Formula of Rulla-Shonomol

$$X = 100.\ \frac{Pt(Zp - Sp)}{Zt(Zp - Sp}$$

(b) Formula of Scheibler

$$X = 100.\ \frac{Pp - Sp}{Zp - Sp}$$

(c) Formula of Neumann

$$X = 100.\ \frac{Pt - St}{Zt - St}$$

Note: Formula (a) is generally serviceable, even when the syrups are diluted; formula (b) and (c) can only be used when there is no dilution of syrups from the centrifugals.

4. SATURATION FORMULA FOR SYRUPS

A saturated syrup of real purity q, at the temperature t, has the following composition, (water content W, sugar content Z) when the saturation conditions of a pure sugar solution at temperature t = Lt (see table 4) and the saturation coefficient = C.

$$W = \frac{L \quad q}{Lt.c + .01q}$$

$$Z = (100 - W) \frac{q}{100}$$

For the supersaturated solutions, the supersaturated coefficient c1 must be also used.

$$W = \frac{q}{Ltc.c1 - .01q}$$

5. STEAM

(a(Total heat of saturated steam.

$a = 606.5 + .305\ t.$

(b) Latent heat

$r = 606.5 - .695\ t.$ (When t designates temperature of the steam)

(c) D = Quantity of steam to evaporate 1 kg H20

When ts = = Temperature of boiling juice.

td = " " steam.

tc = " " condensed water from steam.

$$D = \frac{606.5 - .695\ ts}{606.5 + .305\ td - tc}$$

When td = tc

$$D = \frac{606.5 - .695\ ts}{606.5 - .695\ td}$$

(d) D = Quantity steam to heat 1 kg juice in heaters.

Note: Formula (a) is generally serviceable, even when the syrups are diluted; formula (b) and (c) can only be used when there is no dilution of syrups from the centrifugals.

4. SATURATION-FORMULA FOR SYRUPS

A saturated syrup of real purity q, at the temperature t, has the following composition, (water content W, sugar content Z) when the saturation conditions of a pure sugar solution at temperature t = 1/t (see table 4) and the saturation coefficient = C.

$$W = \frac{1}{1/t.c + .01q}$$

$$Z = \frac{q}{100}\ (100 - W)$$

For the supersaturated solutions, the supersaturated coefficient ci must be also used.

$$W = \frac{1}{1/t.ci + .01q}$$

5. STEAM

(a) Total heat of saturated steam.

$$s = 606.5 + .305\ t.$$

(b) Latent heat

$$r = 606.5 - .695\ t.$$ (When t designates temperature of the steam)

(c) D = Quantity of steam to evaporate 1 Kg. H2O

When te = Temperature of boiling juice.

" td = " " steam.

" to = " " condensed water from steam.

$$D = \frac{606.5 - .695\ te}{606.5 + .305\ td - to}$$

When td = to

$$D = \frac{606.5 - .695\ te}{606.5 - .695\ td}$$

(d) D = Quantity steam to heat 1 Kg juice in heaters.

When td = Temperature of steam.

tc = " " condensed steam.

t1 = " " juice entering.

t2 " " juice leaving.

$$D = \frac{t2 - t1}{606.5 + .305\ td - tc}$$

(e) By open coils amount steam to heat kg juice

$$D = \frac{t2 - t1}{606.5 + .305\ td - t2}$$

CONDENSATION OF STEAM.

W = Amount of water to condense 1 kg steam.

td = Temperature of steam

te = " " H20 entering condenser.

tp = " " " in tail pipe.

$$W = \frac{606.5 + .305\ td - tp}{tp - te}$$

Where td = Temperature of steam.

tc = " " condensed steam.

t1 = " " juice entering.

t2 " " juice leaving.

$$D = \frac{t2 - t1}{606.5 + .305\ td - tc}$$

(c) By open coils amount steam to heat kg juice

$$D = \frac{t2 - t1}{606.5 + .305\ td - t2}$$

CONDENSATION OF STEAM.

W = Amount of water to condense 1 kg steam.

td = Temperature of steam

te = " " H2O entering condenser.

tp = " " " " in tail pipe.

$$W = \frac{606.5 + .305\ td - tp}{tp - te}$$

Appendix II.

The calculation and diagramatic presentation of an evaporation plant and of the steam consumption for the working of 220 lbs., of beets per minute.

As already mentioned in Chapter XII, we can use many different installations to procure high evaporative efficiency from steam. One of the simplest and cheapest arrangements which affords opportunity for the use of a very small amount of steam, will be described and worked out in the following. This calculation is not absolutely correct, and is only given as an example, ignoring many of the minor items. In spite of this, the figures will be close enough to be useful in showing the simplest method of making such calculations for practical purposes.

As a basis for these calculations, we will take the following figures:---

Beet consumption 220 lbs., per minute, i.e. 158 tons per day, and assume the rate of manufacture is constant. For very obvious reasons, all apparatus should have a greater capacity than is necessary for average working conditions. The heating surfaces calculated here, give practically only a capacity of about 110 tons per day. For larger factories, the corresponding conditions can be easily obtained by using the figures found here as factors. We will begin by calculating the diffusion battery juice as 242 lbs., and thin juice 246 lbs. per 220 lbs. beets.

The thin juice will be evaporated from 12° to 60° Brix in the evaporators, so that 80% of it, or 211 lbs., of water, are evaporated for every 220 lbs., of beets, and 53 lbs. of thick juice are obtained. From the thick juice we obtain by boiling, 33 lbs. of fillmass, so that 20 lbs. of water are evaporated in the vacuum pans. In boiling the

Appendix II.

The calculation and diagrammatic presentation of an evaporating plant and of the steam consumption for the working of 220 lbs. of beets per minute.

As already mentioned in chapter XII., we can use many different installations to procure high evaporative efficiency from steam. One of the simplest and cheapest arrangements which affords opportunity for the use of a very small amount of steam, will be described and worked out in the following. This calculation is not absolutely correct, and is only given as an example, ignoring many of the minor items. In spite of this, the figures will be close enough to be useful in showing the simplest method of making such calculations for practical purposes.

As a basis for these calculations, we will take the following figures:—

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and assume the rate of manufacture is constant. For very obvious reasons, all apparatus should have a greater capacity than is necessary for average working conditions. The heating surface calculated here, give practically only a capacity of about 110 tons per day. For larger factories, the corresponding conditions can be easily obtained by using the figures found here as factors. We will begin by calculating the diffusion battery juice as 242 lbs., and this juice 246 lbs. per 220 lbs beets.

The thin juice will be evaporated from 13° to 60° Brix in the evaporators, so that 80% of it, or 217 lbs. of water are evaporated for every 220 lbs. of beets and 51 lbs. of thick juice obtained. From the thick juice we obtain by boiling 23 lbs. of fitmass, so that 30 lbs. of water are evaporated in the vacuum pans. In boiling the

syrup 2.2 lbs. of water must be evaporated for every 220 lbs of beets.

The amount of exhaust steam will be about 66 lbs. for every 220 lbs. of beets, in case good engines are used taking steam at full stroke.

For evaporation, we will consider a Quadruple Effect with a juice boiler. The heating of the raw juice takes place in a preheater, heated by the vapors from the last body of the evaporators. In this the temperature of the liquor is raised from 86 to 122°F., then by means of the vapors from Body II, from 122° to 176°F. The thick juice and syrup should be boiled; and the diffusion, the saturation, the thin and the thick juice should be heated with the vapors from Body 1.

The 1st body of the Quadruple Effect, should be heated with the exhaust steam from the engines, which in cases of deficiency should be supplied by vapors from the juice boiler in conjunction with the exhaust steam. The juice boiler should be heated with high pressure steam, so that all heat used for evaporation, boiling and preheating apparatus, comes from vapors of the juice boiler, added to the exhaust, and no live steam is used anywhere else. For preheating purposes the following heat quantities are necessary:-----

1. For Diffusion

242 lbs. diffusion juice from 50 to 86°F.= 242 x 36 = 8,710. B.T.U.
440 " pulp and press water from 50°to 68° F. = 440 x 18 = 7,920. B.T.U.

Cooling about 18° during diffusion for 440 lbs. battery volume to 220 lbs. beets gives a heat consumption of 440 x 18= 7,920.B.T.U.

Total heat consumption for diffusion is 24,550 B.T.U.= 25.73 lbs. steam from Body 1.

2. For preheating the diffusion in preheater 1 with vapors from Body IV.

242·(122 - 86)= 8,710 B.T.U.= 8.8 lbs. condensed vapors from IV.

syrup 2.2 lbs. of water must be evaporated for every 220 lbs of beets.

The amount of exhaust steam will be about 66 lbs. for every 220 lbs. of beets, in case good engines are used taking steam at full

For evaporation, we will consider a Quadruple Effect with a juice boiler. The heating of the raw juice takes place in a preheater, heated by the vapors from the last body of the evaporators. In this the temperature of the liquor is raised from 86 to 122°F., then by means of the vapors from Body II. from 122° to 176°F. The thick juice and syrup should be boiled; and the diffusion, the saturation, the thin and the thick juice should be heated with the vapors from Body I.

The last body of the Quadruple Effect, should be heated with the exhaust steam from the engines, which in cases of deficiency should be supplied by vapors from the juice boiler in connection with the exhaust steam. The juice boiler should be heated with high pressure steam, so that all heat used for evaporation, boiling and preheating apparatus, comes from vapors of the juice boiler added to the exhaust, and no live steam is used anywhere else. For preheating purposes the following heat quantities are necessary:-----

1. For Diffusion

240 lbs. diffusion juice from 50 to 86°F. = 240 x 36 = 8,710. B.T.U.
440. " pulp and press water
From 50° to 68° F. = 440 x 18 = 7,920. B.T.U.

cooling about 18° during diffusion for 440 lbs. pulp, leaving vol-
ume to 220 lbs. beets gives a heat consumption of 440 x 18 = 7,920. B.T.U.

Total heat consumption for diffusion is 24,550. B.T.U. = 25.72
lbs. steam from body I.

2. For preheating the diffusion in preheater 1 with vapors from
Body IV.

240 (122 - 86) = 8,710 B.T.U. = 8.8 lbs. condensed vapors from IV.

3. For preheating the diffusion juice in preheater II with vapors from Body II.

242 (176 - 122)= 13,070 B.T.U.= 73.4 lbs. condensed vapors from II.

4. For preheating the saturation juice from 176° to 194° and to make up for a cooling loss of 9° F.

264 (194 - 176 + 9)= 7,130 B.T.U.= 7.48 lbs. steam from I.

5. For preheating the thin juice from 194° to 212° F. and make up for a cooling loss of 9° F.

264 (212 - 194 + 9)= 7,130 B.T.U.= 7.48 lbs. steam from I.

6. For preheating the 53 lbs. of thick juice from 140 to 194 (Sp.heat of thick juice = 0.60).

53 (194 - 140) 0.60 = 1,720 B.T.U.= 1.76 lbs. steam from I.

7. To boil the thick juice, i. e. to evaporate 19.8 lbs. of water from it.

19.8 x 834 = 16,500 B.T.U. = 20.21 lbs. steam from I.

8. To boil and preheat the syrup, i.e. for evaporating 22 lbs. of water and heating 11 lbs. of syrup.

2,300 B.T.U. = 2.42 lbs. of steam from I.

Hence, for boiling and preheating, the Quadruple Effect has to supply the following amounts of steam:----

From Body	I	25.73	+	7.48	+	7.48	+	1.76	+	20.21	+	2.42	=	65.1
" "	II	"		"		"		"		"		"	=	13.4
" "	IV	"		"		"		"		"		"	=	8.8

Designating the amount of water which is evaporated in the last Body IV by x, then there must be evaporated in Body I, x + 65.1 + 13.4, in II, x + 13.4, in III, x, in IV, x lbs. The juice boiler has to supply as much heat as Body I of the Quadruple Effect needs, from the 66 lbs. of exhaust steam, and must evaporate

$$x + 65.1 + 13.4 - 66 = x + 12.5 \text{ lbs.}$$

The total amount of water which has to be evaporated for every 220 lbs. of beets is 211 lbs.; hence, we can solve the equation for x :----

$$211 = (x + 12.5) + (x + 78.5) + (x + 13.4) + x + x.$$

$$x = 21.3 \text{ lbs.}$$

In the apparatus of the evaporating plant we have to evaporate the following amounts of water for 220 lbs. of beets:--

	Evaporated	Heat transferred.
In juice boiler	33.9 lbs. water	32,400 B.T.U.
" Body I	100.0	95,600 "
" " II	34.8	33,850 "
" " III	21.2	21,080 "
" " IV	21.2	21,570 "
	211.0	

For this evaporation and for all boiling and heating purposes we need in steam

Engine Exhaust Steam - - -- - - - - - - - - - - - - - - 66.0 lbs.

Direct boiler steam for juice boiler 33.9 x 1.05 = 35.6

101.6 lbs.

If in place of a number of non-expansion engines, a few large modern expansion engines and pumps are used, the quality of exhaust steam is apt to be smaller and the juice boiler can receive more high pressure steam.

Besides the 101.6 lbs of steam for the evaporation, and the preheating and boiling in connection with it, the boiler plant must supply the following amounts of steam:---

1. The steam that is condensed in the engines and pipes on its way from the boiler through the engines to Body I. With engines taking steam at full stroke, this amounts to about 20% of the exhaust steam that gets to Body I; hence, 13.2 lbs. in our example.

The steam quantities which is lost in cooling in the evaporating and boiling apparatus and the vapor lines; and that which is used for steaming out and other purposes or is lost in leaks. These quantities can only be guesses at, and amount to about 10 to 20% of the total steam used.

Hence, the boiler house has to supply the steam for

Evaporating, Boiling and preheating		101.6 lbs.
Losses in engines and pipe lines		13.2 "
Other losses	11.4 to	22.9 "
	126.2	137.7 "

A sugar factory with an evaporating plant as described needs only about 7.5 lbs. of Anthracite coal, when it is possible to obtain an evaporation of 8 lbs. of water per pound of coal. In Germany the steam and coal consumption is from 1/4 to 1/2 % higher than it should be, due to the shut downs on Sundays.

The quantities of vapor to be condensed on one central, or a number of smaller condensors, amounts to 12.3 lbs., from the evaporators and 22.0 lbs from the vacuum pans, or a total of 34.3 lbs. The quantities of condensed vapors per 100 kg of beets are made up about as follows:----

(a). Water above 100° C.

From the exhaust pipe	6.0 kg.
" " Juice Cooker	15.4 "
" " #1 Body Evaporator	45.4 "
" " #2 " "	15.8 "
	82.6 kg.

(b). Water at about 100° C.

From the Vacuum Pans	10.3 kg.
" " #3 Body Evaporator	9.7 "
" " Thin Juice Heater	3.4 "
" " Thick " "	0.8 "
	24.2 kg.

(c). Water below 90° C.

From the #4 Body Evaporator	9.7 kg.
" " Diffusion Heaters	11.7 "
" " " Juice Reheaters	10.1 "
" " Saturation Coils	3.4 "
	34.9 kg.

Total Water for 100 kg beets 141.7 kg.

The calculations for the heating surfaces is shown in the following table. As the coefficient of transmission of heat is the heat transmitted to each sq. ft., in 1 minute for each degree difference in temperature, one has to divide the steam quantities used per minute, as given above, for each separate apparatus, by the product of the temperature drop and the coefficient of transmission of heat in order to obtain the area of the heating surfaces. As the temperatures drop, we have to use in the case of preheaters the differences between the temperatures of the steam and the mean temperatures of the juice flowing in and out. In case of the evaporating and boiling apparatus, the differences between the steam and that of the boiling juice must be used.

The following calculations are for the heating surfaces for working 220 lbs. of beets per minute, corresponding in practice to a working of 110 tons per day.

Apparatus	Heat transferred	Temp.Drop.	Coeff.	Heat. Surf.
Juice Boiler	32,400 B.T.U.	18.0° F	105.0	172 Sq.Ft.
Body I	95,500 "	14.5	91.0	720
" II	33,800	16.0	61.5	344
III	21,100	18.0	40.5	290
IV	21,500	30.5	24.3	290
Raw Ju. Pre-H I	8,740	45.0	10.2	194
" " " II	13,100	63.0	10.2	215
Saturation "	7,150	36.0	10.2	194
Thin Juice "	7,150	18.0	20.4	194
Thick " "	1,710	54.0	10.2	32
Pan for I Prod.	19,700	54.0	20.4	183
Syrup Boiler	23,300	54.0	10.2	43
	285,150			2871

The calculations for the heating surfaces is shown in the following table. As the coefficient of transmission of heat is the heat transmitted to each sq. ft., in 1 minute for each degree difference in temperature, one has to divide the steam quantities used per minute, as given above, for each separate apparatus, by the product of the temperature drop and the coefficient of transmission of heat in order to obtain the area of the heating surfaces. As the temperatures drop, we have to use in the case of preheaters the difference between the temperatures of the steam and the mean temperatures of the juice flowing in and out. In case of the evaporating and boiling apparatus, the differences between the steam and that of the boiling juice must be used.

The following calculations are for the heating surfaces for working 250 lbs. of beets per minute, corresponding in practice to a working of 110 tons per day.

Apparatus	Heat transferred	Temp.Drop.	Coeff.	Heat. Surf.
Juice Boiler	32,400 B.T.U.	18.0° F	105.0	172 Sq.Ft.
Body I	95,500 "	14.5	91.0	720
" II	33,800	18.0	61.5	544
III	21,100	18.0	40.5	290
IV	21,500	30.5	24.5	290
Raw Jc. Pre-H I	8,740	45.0	10.2	194
" " " II	13,100	83.0	16.2	215
Saturation "	7,150	36.0	10.2	194
Thin Juice "	7,150	18.0	20.4	194
Thick " "	1,710	54.0	10.2	32
Pan For I Prod.	19,700	54.0	20.4	183
Syrup Boiler	23,350	54.0	16.4	42
	285,150			2871

As the boiling apparatus for thick juices and syrups do not work constantly, and as the juices are not all boiled with the same ease, it is necessary to add 50 to 100% to the calculated heating surfaces to these apparatuses. An increased surface is also necessary for the evaporators, unless they are thoroughly cleaned every week.

The necessary heating surfaces of the boilers for supplying 123 lbs. of steam per minute, can be determined on the following empirical basis:---

In order to obtain a good economy in coal, the steaming capacity in a return tubular boiler, should not be more than 1.85 - 2.32 lbs. of steam, per sq.ft., per hour; or 0.032 - 0.037 lbs. steam per minute. In water tube boilers, this rate should not exceed 1.10 to 1.40 lbs. steam per sq.ft. per hour or 0.018 - 0.023 lbs per minute. Hence, for generating 132 lbs. of steam per minute i.e. for generating steam for working 158 tons per day, the following heating surfaces are essential:-----

In return tubular boilers	1,830 - 2,150 sq.ft.
In water tube boilers	2,580 - 3,230 "

For a daily working of 110 tons of beets, the following heating surfaces will suffice:-----

In return tubular boilers	1,290 - 1,505 sq.ft.
In water tube boilers	1,830 - 2,260 "

Heat balance of the factory calculated on a basis of 100 kg of beets:----

(a). Heat losses in boiler house.

Burnt 7 kg. coal at 7,000 calories = 49,000 calories.

Obtained 60 " steam " 560 " = 33,600 " = 68.6%

15,400 " = 31.4%

As the boiling apparatus for thick juices and syrups do not work constantly, and as the juices are not all boiled with the same ease, it is necessary to add 50 to 100% to the calculated heating surface to these apparatuses. An increased surface is also necessary for the evaporators, unless they are thoroughly cleaned every week.

The necessary heating surfaces of the boilers for supplying 1024 lbs. of steam per minute, can be determined on the following empirical basis:—

In order to obtain a good economy in coal, the steaming capacity in a return tubular boiler, should not be more than 1.66 - 2.32 lbs. of steam, per sq.ft., per hour; or 0.028 - 0.037 lbs. steam per minute. In water tube boilers, this rate should not exceed 1.10 to 1.40 lbs. steam per sq.ft. per hour or 0.018 - 0.023 lbs per minute. Hence, for operating 132 lbs. of steam per minute i.e. for 96 hours steaming for working 156 tons per day, the following heating surfaces are essential:—

In return tubular boilers 1,880 - 2,640 sq.ft.

In water tube boilers 2,580 - 3,520 "

For a daily working of 117 tons of beets, the following heating surfaces will suffice:—

In return tubular boilers 1,320 - 1,760 sqft.

In water tube boilers 1,830 - 2,560 "

Heat balance of the factory calculated on a basis of 100 kg of beets:—

(a). Heat losses in boiler house.

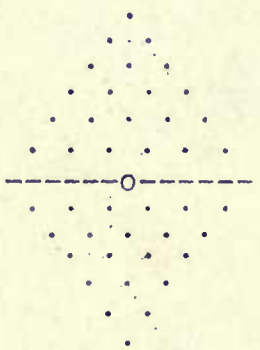
Burnt 7 Kg. coal at 7,500 calories = 49,000 calories.

Obtained 60 " steam " 550 " = $\frac{33,000}{16,450}$ " = 67.3%

(b). Heat losses in the factory.

(Percentages based on the steam, 33,600. Cals.).

1. On the way from boiler house to place of utilization - - - - - - - - - -	3,360.	Cals. =	10 %
2. In tail pipe water. For the condensation of 20 kg. of vapor at 630 calories - - - - - - - - - -	12,600	" =	37.5%
3. In waste waters of diffusion 200 kg at 10 calories - - - - - - - - - -	2,000	" =	6.0%
4. In press cake 10 kg. at 60 calories - - - - - - - - - -	600	" =	1.7%
5. Condensed vapors 60 kg. at 80 calories - - - - - - - - - -	4,800	" =	14.3%
6. In fillmasses I and II. 20 kg (.5 Sp heat) cooled to 70°C.- - -	700	" =	2.1%
Total determinable losses	24,060	Cals.	71.6%
Undeterminable "	9,540	"	28.4%



(b). Heat losses in the factory.

(Percentages based on the steam, 33,360 cals.)

1. On the way from boiler house
to place of utilization - - - - - - - - - - - - - - - - 3,360 cals. = 10 %

2. In test pipe water. For the
condensation of 20 Kg. of
vapor at 630 calories - - - - - - - - - - - - - - 12,600 " = 37.5%

3. In waste waters of diffusion
200 Kg at 10 calories - - - - - - - - - - - - - - - 2,000 " = 6.0%

4. In press cake
10 Kg. at 60 calories - - - - - - - - - - - - - - - - 600 " = 1.7%

5. Condensed vapors
60 Kg. at 80 calories - - - - - - - - - - - - - - - 4,800 " = 14.3%

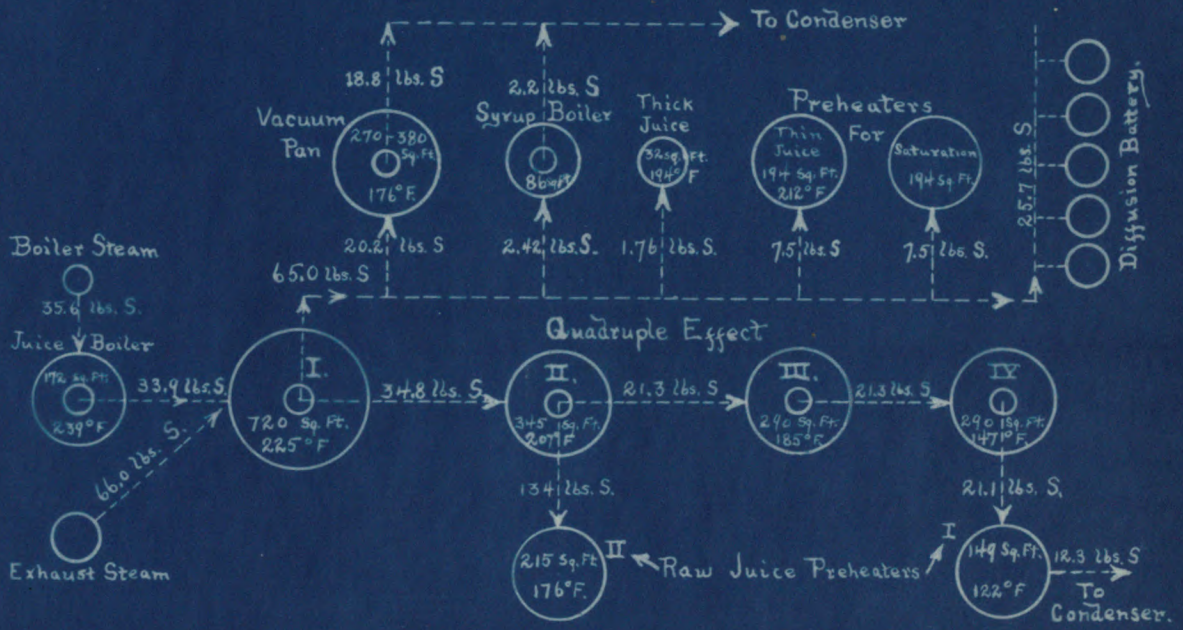
6. In filtrasses I and II.
20 Kg (.5 Sp heat) cooled to 70° - - - - - - - - - - 700 " = 2.1%

Total determinable losses - - - 24,060 cals. 71.8%

Undetermined " - 9,540 " 28.4%

DIAGRAM

Showing heating arrangement of a factory working 220 lbs. of beets per minute, which corresponds to a daily capacity of 110 tons of beets.



EXPLANATION

The arrows show the direction in which the steam (S) travels from one apparatus to another. The figures on the dotted lines give the amount of steam utilized in each apparatus; the heating surfaces are given in square feet, and temperatures in degrees F. In the evaporators the temperatures are those of the vapors entering each body, in the other apparatus the temperatures are of the juices.

TABLES.

Table of Solubility of Lime in Water.
Herzfeld. (Deutche Vereinszeitschrift 1897. S. 819).

At	15°	C.	1	part	CaO	requires	776	parts	of water.
"	20	"	"	"	"	"	813	"	" "
"	25	"	"	"	"	"	848	"	" "
"	30	"	"	"	"	"	885	"	" "
"	35	"	"	"	"	"	924	"	" "
"	40	"	"	"	"	"	962	"	" "
"	45	"	"	"	"	"	1004	"	" "
"	50	"	"	"	"	"	1044	"	" "
"	55	"	"	"	"	"	1108	"	" "
"	60	"	"	"	"	"	1158	"	" "
"	65	"	"	"	"	"	1244	"	" "
"	70	"	"	"	"	"	1330	"	" "
"	75	"	"	"	"	"	1410	"	" "
"	80	"	"	"	"	"	1482	"	" "

2. Solubility of Lime in Sugar Solution.
According to Lamy, 100 gm. of a 10% sugar solution dissolves:-

At	0°	25.0	gm. CaO.
"	15	21.5	" "
"	30	12.0	" "
"	50	5.3	" "
"	70	2.3	" "
"100	.....	1.55	" "

Note: The solubility of Lime in a sugar solution depends, not alone on the temperature and the amount of sugar, but also on the quantity and method of adding the lime and the time of acting.

3. Table of the amount of CaO contained in Milk of Lime at 15° C.
(According to Blattner).

Degree Bé	Wt. of Milk of Lime gr.	CaO in 1 Litre gr.	% by wt.	Deg. Bé	Wt. of Milk of Lime	CaO in 1 Litre	% by wt.
1	1007	7.5	0.745	16	1125	159	14.13
2	1014	16.5	1.64	17	1134	170	15.00
3	1022	26.0	2.54	18	1142	181	15.85
4	1029	36.0	5.50	19	1152	193	16.75
5	1037	46.0	4.43	20	1162	206	17.72
6	1045	56.0	5.36	21	1171	218	18.61
7	1052	65.0	6.18	22	1180	229	19.40
8	1060	75.0	7.08	23	1190	242	20.34
9	1067	84.0	7.87	24	1200	255	21.25
10	1075	94.0	8.74	25	1210	268	22.15
11	1083	104.0	9.60	26	1220	281	23.03
12	1091	115.0	10.54	27	1231	295	23.96
13	1100	126.0	11.45	28	1241	309	24.90
14	1108	137.0	12.35	29	1252	324	25.87
15	1116	148.0	13.26	30	1263	339	26.84

T A B L E S.

1. Solubility of Lime in Water.

Vertical. (Deutsche Vereinszeitschrift 1897. S. 819).

At 15° C.	1	Part CaO	requires	770	Parts of Water.
" 20	"	"	"	815	" " "
" 25	"	"	"	848	" " "
" 30	"	"	"	885	" " "
" 35	"	"	"	934	" " "
" 40	"	"	"	982	" " "
" 45	"	"	"	1004	" " "
" 50	"	"	"	1044	" " "
" 55	"	"	"	1100	" " "
" 60	"	"	"	1158	" " "
" 65	"	"	"	1214	" " "
" 70	"	"	"	1250	" " "
" 75	"	"	"	1410	" " "
" 80	"	"	"	1482	" " "

2. Solubility of Lime in Sugar Solution.

According to Leplay, 100 Gm. of a 10% sugar solution dissolves:-

At 0°	25.0	Gm. CaO.
" 15	21.5	" "
" 50	12.0	" "
" 80	5.3	" "
" 90	2.3	" "
"100	1.55	" "

Note: The solubility of Lime in a sugar solution depends, not alone on the temperature and the amount of sugar, but also on the quantity and method of adding the lime and the time of boiling.

3. Table of the amount of CaO contained in Milk of Lime at 15° C.

(According to Blattner).

Degree Bé Milk of Lime	1 Litre	Gm. CaO in Wt.	Deg. Bé	Milk of Lime	1 Litre	Gm. CaO in Wt.
1	1007	7.5	16	1125	159	14.13
2	1014	15.5	17	1134	170	15.00
3	1022	23.0	18	1142	181	15.85
4	1029	30.0	19	1152	193	16.75
5	1037	46.0	20	1165	206	17.72
6	1046	56.0	21	1171	218	18.61
7	1052	66.0	22	1180	229	19.40
8	1060	76.0	23	1190	242	20.34
9	1067	84.0	24	1200	255	21.25
10	1075	94.0	25	1210	268	22.16
11	1083	104.0	26	1220	281	23.03
12	1091	116.0	27	1231	295	23.96
13	1100	126.0	28	1241	309	24.90
14	1108	137.0	29	1252	324	25.87
15	1116	146.0	30	1262	339	26.64

4. Table showing the Solubility of Sugar in Water at different Temperatures, according to Herzfeld. Recalculated.

(Deutsche Vereinszeitschrift 1893. S. 181).

In 1 Part of Water, the following parts of Sugar are dissolved:-

Temp. °C.	Parts Sugar	Temp. °C.	Parts Sugar	Temp. °C.	Parts Sugar	Temp. °C.	Parts Sugar
0	1.79						
1	1.80	26	2.12	51	2.62	76	3.44
2	1.81	27	2.14	52	2.65	77	3.48
3	1.82	28	2.16	53	2.67	78	3.52
4	1.83	29	2.17	54	2.70	79	3.57
5	1.84	30	2.19	55	2.73	80	3.62
6	1.86	31	2.21	56	2.75	81	3.66
7	1.87	32	2.23	57	2.78	82	3.71
8	1.88	33	2.25	58	2.81	83	3.76
9	1.89	34	2.27	59	2.84	84	3.81
10	1.90	35	2.29	60	2.87	85	3.86
11	1.91	36	2.30	61	2.90	86	3.92
12	1.92	37	2.32	62	2.93	87	3.98
13	1.94	38	2.34	63	2.96	88	4.03
14	1.96	39	2.36	64	2.99	89	4.09
15	1.97	40	2.38	65	3.03	90	4.15
16	1.98	41	2.40	66	3.06	91	4.21
17	1.99	42	2.42	67	3.09	92	4.28
18	2.01	43	2.44	68	3.13	93	4.35
19	2.02	44	2.46	69	3.16	94	4.42
20	2.04	45	2.48	70	3.20	95	4.48
21	2.05	46	2.51	71	3.24	96	4.55
22	2.07	47	2.53	72	3.28	97	4.63
23	2.08	48	2.55	73	3.31	98	4.71
24	2.09	49	2.58	74	3.35	99	4.79
25	2.11	50	2.60	75	3.40	100	4.87

4. Table showing the solubility of sugar in water at different temperatures, according to Herzfeld. Neoplatated.

(Deutsche Zeitschrift f. Rübenzucker-Ind. 1883. S. 161).

In 1 Part of Water, the following parts of Sugar are dissolved:-

Temp. °C.	Parts Sugar	Temp. °C.	Parts Sugar	Temp. °C.	Parts Sugar
0	1.78				
1	1.80	26	2.12	51	3.69
2	1.81	27	2.14	52	3.65
3	1.82	28	2.16	53	3.67
4	1.83	29	2.17	54	3.70
5	1.84	30	2.19	55	3.73
6	1.86	31	2.21	56	3.76
7	1.87	32	2.23	57	3.78
8	1.88	33	2.25	58	3.81
9	1.89	34	2.27	59	3.84
10	1.90	35	2.29	60	3.87
11	1.91	36	2.30	61	3.90
12	1.93	37	2.32	62	3.93
13	1.94	38	2.34	63	3.96
14	1.96	39	2.36	64	3.99
15	1.97	40	2.38	65	4.02
16	1.98	41	2.40	66	4.05
17	1.99	42	2.42	67	4.09
18	2.01	43	2.44	68	4.12
19	2.02	44	2.46	69	4.16
20	2.04	45	2.48	70	4.20
21	2.05	46	2.51	71	4.24
22	2.07	47	2.53	72	4.28
23	2.08	48	2.55	73	4.31
24	2.09	49	2.58	74	4.35
25	2.11	50	2.60	75	4.40
					100
					4.87

6. Tables showing the Boiling Points of Sugar Solutions.

Calculated according to Flourens
(Bulletin de d'Assoc.1876 Nr.17) and also according to Claassen-Frentzel

(A) Boiling point for Pure Sugar Solution
(a) General Table based on the Sugar Content.

% Sugar	Boiling Point at 760 mm. pressure	Increase in Boiling Point
10	100.1	0.1
20	100.3	0.3
30	100.6	0.6
40	101.1	1.1
50	101.9	1.9
55	102.4	2.4
60	103.1	3.1
65	103.9	3.9
70	105.3	5.3
75	107.4	7.4
80	110.3	10.3
85	114.5	14.5
90	122.6	22.6

(b) Table for the higher Density according to the Water Content.

% Water.	Increase in the Boiling Point Degrees C.	% Water.	Increase in the Boiling Point Degrees C.
25	7.35	13.5	16.9
24.5	7.85	13.25	17.3
24	7.9	13	17.7
23.5	8.2	12.75	18.05
23	8.5	12.50	18.45
22.5	8.8	12.25	18.85
22	9.1	12	19.25
21.5	9.4	11.75	19.65
21	9.7	11.50	20.05
20.5	10.0	11.25	20.45
20	10.35	11	20.85
19.5	10.7	10.75	21.3
19	11.05	10.50	21.7
18.5	11.4	10.25	22.15
18	11.8	10	22.6
17.5	12.2	9.75	23.05
17	12.6	9.50	23.55
16.5	13.1	9.25	24.0
16	13.7	9	24.55
15.5	14.3	8.75	25.05
15	14.9	8.50	25.7
14.5	15.5	8.25	26.5
		8	27.9
14	16.2	7.75	30.0
13.75	16.5		

6. Tables showing the Boiling Points of Sugar Solutions.

Calculated according to Plowrens
(Bulletin de d'Assoc. 1876 Nr.17) and also according to Claassen-Frentzel

(A) Boiling point for Pure Sugar Solution
(a) General Table based on the Sugar content.

% Sugar	Boiling Point at 760.mm. pressure	Increase in Boiling Point
10	100.1	0.1
20	100.3	0.3
30	100.6	0.6
40	101.1	1.1
50	101.9	1.9
55	102.4	2.4
60	103.1	3.1
65	103.9	3.9
70	105.3	5.3
75	107.4	7.4
80	110.3	10.3
85	114.5	14.5
90	122.6	22.6

(b) Table for the higher Density according to the Water content.

% Water.	Increase in the Boiling Point Degrees C.	% Water.	Increase in the Boiling Point Degrees C.
25	7.35	13.5	16.9
24.5	7.85	13.25	17.3
24	7.9	13	17.7
23.5	8.2	12.75	18.05
23	8.5	12.50	18.45
22.5	8.8	12.25	18.85
22	9.1	12	19.25
21.5	9.4	11.75	19.65
21	9.7	11.50	20.05
20.5	10.0	11.25	20.45
20	10.35	11	20.85
19.5	10.	10;75	21.3
19	11.05	10.50	21.7
18.5	11.4	10.25	22.15
18	11.8	10	22.6
17.5	12.2	9.75	23.05
17	12.6	9.50	23.55
16.5	13.1	9.25	24.0
16	13.7	9	24.55
15.5	14.3	8.75	25.05
15	14.9	8.50	25.7
14.5	15.5	8.25	26.5
		8	27.9
14	16.2	7.75	30.0
13.75	16.5		

(B) Table for Thin and Thick Juice and Syrups.

Degrees Brix.	Increase in Boiling Point of Juice	of Syrups	Degrees Brix	Increase in Boiling Point of Juice	of Syrups
10	0.2	0.3	55	2.8	3.4
20	0.4	0.6	60	3.5	4.2
30	0.8	1.1	65	4.4	5.3
40	1.4	1.7	70	5.8	6.8
50	2.2	2.7	75	---	8.5

7. Table showing the Specific Heat of Sugar Solutions.

According to Curin (Oest. Zeitschrift 1894. S. 988).

Degrees Brix.	Specific Heat Kopp	Marignac	Degrees Brix.	Specific Heat Kopp	Marignac
1	0.993	0.994	60	0.605	0.652
10	0.934	0.942	70	0.539	0.594
20	0.868	0.884	80	0.474	0.536
30	0.803	0.826	90	0.408	0.478
40	0.737	0.768	99	0.349	0.426
50	0.671	0.710			

(B) Table for Thin and Thick Juice and Syrups.

Degrees Brix.	Increase in Boiling Point of Juice	Increase in Boiling Point of Syrups	Degrees Brix	Increase in Boiling Point of Juice	Increase in Boiling Point of Syrups
10	0.2	0.3	55	2.8	3.4
20	0.4	0.6	60	3.5	4.2
30	0.8	1.1	65	4.4	5.3
40	1.4	1.7	70	5.8	6.8
50	2.2	2.7	75	---	8.5

7. Table showing the Specific Heat of Sugar Solutions.

According to Gerlach (Dingl. Zeitschrift 1894. S. 388).

Degrees Brix.	Specific Heat Kopp	Specific Heat Marigrac	Degrees Brix.	Specific Heat Kopp	Specific Heat Marigrac
1	0.993	0.994	60	0.605	0.652
10	0.954	0.942	70	0.539	0.594
20	0.868	0.884	80	0.474	0.536
30	0.805	0.826	90	0.408	0.478
40	0.737	0.768	99	0.349	0.426
50	0.671	0.710			

8. Table showing the Loss of Sugar when Boiling Alkaline Juice.

According to Herzfeld. (Deutche Vereinszeitschrift 1893. S. 754).

Loss of Sugar based on 100 parts Sugar entered per hour.

Boiling Point °C.	Percent Sugar in Juice				
	10%	20%	30%	40%	50%
80	0.0444	0.0301	0.0157	0.0179	0.0200
85	0.0615	0.0421	0.0223	0.0262	0.0296
90	0.0790	0.0541	0.0290	0.0344	0.0392
95	0.0965	0.0661	0.0357	0.0427	0.0488
100	0.1140	0.0781	0.0423	0.0508	0.0584
105	0.1385	0.0937	0.0490	0.0588	0.0680
110	0.1630	0.1093	0.0557	0.0667	0.0776
115	0.1749	0.1187	0.0623	0.0748	0.0862
120	0.2823	0.2341	0.1857	0.2269	0.2678
125	0.5330	0.5082	0.4833	0.5939	0.7044
130	2.0553	1.4610	0.8667	1.0235	1.1800
135	3.5776	---	---	---	---
140	5.1000	---	---	---	---

8. Table showing the loss of sugar when Boiling Alkaline Juice.

According to Herzfeld. (Deutsche Zeitschrift 1893. 3, 764).

Loss of Sugar based on 100 parts Sugar entered per hour.

Boiling Point C.	Percent Sugar in Juice				
	10%	20%	30%	40%	50%
80	0.0444	0.0301	0.0157	0.0179	0.0200
85	0.0615	0.0421	0.0223	0.0262	0.0296
90	0.0790	0.0541	0.0290	0.0344	0.0392
95	0.0965	0.0661	0.0357	0.0427	0.0488
100	0.1140	0.0781	0.0423	0.0508	0.0584
105	0.1385	0.0937	0.0490	0.0588	0.0680
110	0.1630	0.1093	0.0557	0.0667	0.0776
115	0.1749	0.1187	0.0623	0.0748	0.0862
120	0.2823	0.1941	0.1857	0.2269	0.2678
125	0.5330	0.5082	0.4833	0.5939	0.7044
130	2.0523	1.4610	0.8667	1.0255	1.1800
135	3.5776	---	---	---	---
140	5.1000	---	---	---	---

9. TABLE SHOWING THE AMOUNT OF STEAM USED FOR HEATING, EVAPORATING AND BOILING THE JUICES. (CLAASSEN).

	Method in which Steam is used.			
	Without using the Vapors. Boiler Steam for Boiling and Heating the Juice	Vapors from I used partially for boiling and heating, Steam for the remaining	Vapors from I (or preheater) for all heating and boiling purposes.	Vapors from I. (Preheater) and II used for all heating and boiling purposes.
Evaporating Apparatus	Amount of Steam used per 100 kg. Beets.			
	kg.	kg.	kg.	kg.
Single Effect	144.4	106.4	96.0	--
Double "	91.6	72.3	67.1	--
Triple "	74.0	60.9	57.5	--
Quadruple "	65.2	55.2	52.6	46.1
Quintuple "	60.0	51.8	49.8	44.5
Sextuple "	56.4	49.6	47.8	42.5

Note:

The amount of thin juice is assumed to be 120 kg on every 100 kg. of Beets.

The amount of heat lost in the mixers and pipes are not comprised in the above.

10. TABLE SHOWING THE INFLUENCE OF PURITY ON THE YIELD

(Claassen, ("D. Zuckerindustrie" 1894. S.956.)

I. THE YIELD FROM RAW SUGAR

(a). Influence on Fillmass purity when the purity of the Green Syrups remains constant at 72°.

FILLMASS		Yield of Raw sugar of 92° Percentage of Fillmass.	Increase in yield with each 1% of Purity
Dry Substance	Purity		
94	88	59.0	---
94	89	62.7	3.7
94	90	66.4	3.7
94	91	70.1	3.7
94	92	73.8	3.7
94	93	77.5	3.7
94	94	81.2	3.7
94	95	84.9	3.7

(b). Influence on Green Syrup purities when the purity of the Fillmass remains constant at 91°.

Syrup Purity	Yield of Raw sugar at 92° Percentage of Fillmass.	Increase of yield with each 1% decrease in Purity.
75	66.7	---
74	67.9	1.2
73	69.1	1.2
72	70.1	1.0
71	71.0	0.9
70	71.9	0.9
69	72.7	0.8
68	73.5	0.8
67	74.2	0.7
66	74.9	0.7

II. ON THE YIELD OF MOLASSES

With a yield of 16% on the Beets of I Product Fillmass, and a real purity of the Molasses of 62, the yield of Molasses (containing 20% water) in percent on Beets is as follows:-

Real purity of Fillmass or thick juice	Average Polarization of Sugars I and II.				
	94	95	96	97	100
	Percentage Molasses on Beets.				
90	3.3	3.6	4.0	4.3	4.9
91	2.7	3.1	3.4	3.8	4.4
92	2.1	2.6	2.9	3.3	4.0
93	1.6	2.0	2.4	2.8	3.5
94	1.1	1.5	1.9	2.4	3.0
95	0.6	0.9	1.4	1.9	2.5
96	0.0	0.4	0.8	1.5	2.0

Weights of Various Volumes.

Raumgewichte.

1 cubic meter of the following weighs:

Beets, washed	550 - 600 kg.	Coke, Westphalian melt	420 kg.
Pulp, fresh	600 "	" Gas	350 "
" soured	800 "	Lime-stone	1600 "
Coal, Westphalian Flame	705 "	Lime	775 - 950 "
" Run of Mine	765 "	Milk of Lime	1200 "
" Slack	770 "	Raw Sugar 1st. Product loosely packed	875 "
" Upper Layer	725 "	" "2nd Prod " "	780 "
" English	735 "	Fillmass (hot)	1450 - 1470
Peat	550 - 750 "		

Specific Gravity.

Sugar	1.61
Lime-stone	2.36 - 2.74
Lime	2.30 - 4.20

Weight of Gases at 0° and 760 mm. Atmospheric Pressure.

1 litre of air	1.293 g.	1 Litre of Carbonic Oxide	1.250 g
" " " Oxygen	1.430 "	" " " Water Vapor at 100° C.	0.506 "
" " " Nitrogen	1.256 "	" " " Hydrogen	0.089 "
" " "Carbonic Acid	1.977 "	" " "Illuminating Gas	0.517
" " "Sulphurous Acid	.2.909g		

Water Vapor - Specific Heat.

At constant pressure	0.4750
" " volume	0.3337

Coefficient of Heat Transmission

(Average figures derived in actual practice)

According to Jelinek in Triple Effect Apparatus

In body	I	37 Heat Units.
" "	II	25 " "
" "	III	14 " "

In Quadruple Effect Qpparatus

In body	I	28 Heat Units.
" "	II	26 " "
" "	III	20 " "
" "	IY	5 to 6 " "

In Syrup Boiler 6 to 7 Heat Units.

Weights of Various Volumes.

Raumgewichte.

1 cubic meter of the following weighs:

Beets, washed	550 - 600 kg.	Coke, Westphalian melt	430 kg.
Pulp, fresh	600 "	" Gas	550 "
" pressed	800 "	Lime-stone	1800 "
Coal, Westphalian Flame	705 "	Lime	775 - 950 "
" Run of Mine	765 "	Milk of Lime	1200 "
" Slack	770 "	Raw Sugar Ist. Product	
" Upper Layer	725 "	Loosely packed	875 "
" English	755 "	" "2nd Prod. "	750 "
Peat	550 - 750 "	Tallmass (wet)	1450 - 1470

Specific Gravity.

Sugar	1.61
Lime-stone	2.58 - 2.74
Lime	2.30 - 4.20

Weight of Gases at 0^{o} and 760 mm. Atmospheric Pressure.

1 Litre of air	1.293 g.	1 Litre of Carbonic Oxide	1.250 g.
" " Oxygen	1.430 "	" " Water Vapor	
" " Nitrogen	1.256 "	at 100^{o} C	0.506 "
" "Carbonic Acid	1.977 "	" " Hydrogen	0.089 "
" "Sulphurous Acid	2.909g "	" "Illuminating Gas	0.517

Water Vapor - Specific Heat.

At constant pressure	0.4750
" volume	0.3537

Coefficient of Heat Transmission
(Average figures derived in actual practice)

According to Jelinek in Triple Effect Apparatus

In body I	37 Heat Units.
" " II	25 " "
" " III	14 " "

In Quadruple Effect Apparatus

In body I	38 Heat Units.
" " II	26 " "
" " III	20 " "
" " IV	5 to 6 " "

In Syrup Boiler 6 to 7 Heat Units.

In Vacuum Pan

Until boiling to grain	18	Heat Units.	
At boiling to grain	10	"	"
Stiffening	3.7	"	"

According to Claassen in the Triple Effect Apparatus

In body	I	Temp. Difference	5.5°	Juice 10°Brix.	40 - 50 Cal.
" "	II	"	7.5	"20 - 25 "	30 - 35 "
" "	III	"	24°	"55 - 62 "	15 - 20 "

According to Sulzer - Laboratory Experiments at Atmospheric temperature have shown:--

Kind of Tube	Guage of Tubing mm	Coefficient of heat transmission at the following Heating Temperatures					
		110	117	125	131.3	136.5	141.6
1. Drawn Copper	2.5		47.3	57.2	63.3	62.3	54.2
2. Painted & Riveted Wrought Iron	2.1		33.3	35.3	35.8	37.7	35.3
3. Unpainted " "Riveted	2.1		38.0	36.7	39.2	39.2	37.8
4. Seamless " "	4.5		40.5	42.8	44.8	45.5	43.3
5. Cast Iron (Crude).	10.0		25.8	32.2	31.5	31.3	32.3
6. Welded Wrought Iron	13.0		23.2	24.7	26.2	25.5	24.7
7. Painted & Riveted Steel	1.85	19.0	28.2	31.3	33.0	38.3	—
8. Smooth Turned Casting	15.25	17.7	20.5	24.5	25.0	26.0	25.7
9. Cast Iron, Corrugated	13.5	26.2	24.8	28.0	28.7	30.0	29.7

In Preheater

with slow circulation	2 - 3	Heat Units.
" rapid "	6 - 10	" "

Utilization of Steam in Manifold Effect.

1 kg. Steam Evaporates in	Single Effect	.9 kg.	Water.
in	Double "	1.96 "	"
"	Triple "	2.85 "	"
"	Quadruple "	3.79 "	"
"	Quintuple "	4.72 "	"

Decomposition of Sugar in Alkaline Solution

1 ccm $\frac{N}{10}$ KOH (containing .0047 g K_2O = 0.0028 g CaO) is neutralized by .012 g. Invert Sugar, or .0114 g. Saccharose.

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